Final Report

Measurements of Atmospheric Emission Spectra in the 8.5μm to 13.3μm and 19.0μm to 26.0μm Regions at High Altitudes and Various Zenith Angles

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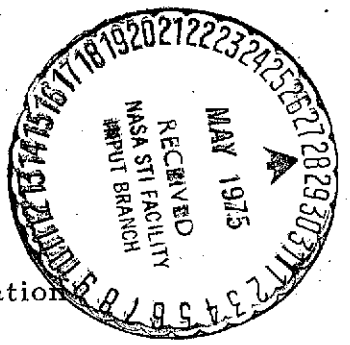

Introduction

The object of this program was to perform a balloon flight with a sensitive infrared spectral radiometer system in support of the LACATE balloon experiment. It was initially planned that the balloon carrying this system should be launched on the same day that the LACATE balloon was launched. As the launch date for the LACATE experiment approached, it became evident that launching the two balloons on the same morning presented a number of logistic problems which almost became prohibitive; so the launch for this program was scheduled to be performed as soon after the LACATE launch as possible. Problems encountered with the liquid helium dewar which houses the balloon borne spectral radiometer system finally forced the balloon launch to be delayed approximately seven weeks while the dewar could be modified. The balloon flight was finally performed on 27 June 1974. The results obtained during that flight are presented in this report.

Instrumentation

The spectrometer used in this study is an 0.4 meter grating spectrometer of Littrow design, in which radiation is double passed in order to increase the resolution obtainable with the system. The spectrometer and a small telescope assembly used to narrow the spectrometer field of view are mounted in a liquid helium dewar; and all components are cooled by liquid helium to less than 8 K. The spectrometer is equipped with a beam splitter behind the exit slit and two Ge:Cu detectors. Using two detectors allows the spectra to be taken in two different orders of the grating. For this flight the filter chosen for the detectors and the beam splitter allowed spectra to be obtained covering the 8.5μm to 13.3μm and the 19.0μm to 26.0μm spectral regions. The spectrometer employs a tuning fork chopper which interrupts the radiation from the entrance slit and results in an ac signal from the detectors. These ac signals

are amplified by means of a preamplifier which is operated inside the helium dewar. After initial amplification the signals are brought out of the dewar, where they are synchronously rectified and further amplified using operational amplifiers. The final system gain can be adjusted over a wide range from the instrument control panel. The data generated are recorded by means of an on-board digital magnetic tape recorder system and also telemetered using an FM/FM telemetry system. Because of the low heat capacity of the liquid helium, a high vacuum is required to reduce the heat load on the helium. As a result a window has to be incorporated into the system of sufficient strength to withstand one atmosphere of pressure. This window is in the optical field of view of the spectrometer; and hence contributes to the background radiation reaching the detector and to the detector noise. In order to reduce the noise due to the window emission, provision is also made to cool this window to 77 K. In order to keep frost from forming on the window, boil-off gas from the liquid nitrogen used to cool the window is vented in front of the window. This cold dry nitrogen gas is contained by a baffle system, which is cooled by the gas and becomes part of the anti-frost system as well as keeping stray radiation from reaching the spectrometer.

Flight Details

The spectrometer system was working, in time for the LACATE flight, with the constraint that the liquid helium hold time at best was seven hours. An attempt was therefore made to perform the flight in early May. In attempting to perform instrumental checkout at Holloman AFB, it became evident that the liquid helium hold time was too variable to risk a balloon flight with the instrument; so the decision was made to delay the flight until the hold time problem could be corrected. Discussions with the dewar manufacturer determined that the cause of the

short hold time was thermal oscillations which originated in the liquid helium fill lines. This problem was corrected by incorporating material in the fill lines, which damped these oscillations. Since these modifications have been completed the dewar hold time consistently exceeds 22 hours. After these modifications were completed the instrumentation was returned to Holloman AFB; and preparations for the balloon flight were completed on 24 June. Weather conditions prevented launch until 27 June. Flight preparations went smoothly and the balloon was launched at 0711 MDT. The balloon ascended at an average ascent rate of 250 m/min and reached a float altitude of 38 km. The instrumentation worked properly and data were obtained from launch through cutdown of the gondola. The flight was terminated at 1404MDT. The instrumentation impacted in the vicinity of Maricopa, Arizona and was recovered in good condition.

Data Reduction

The data generated by the spectrometer consist of voltage versus time signals from the two detectors. The movement of the grating which results in the wavelength scan of the spectrometer is adjustable by means of control circuitry external to the dewar. For this flight it was set so that a spectral scan took 43 seconds to complete. The ac signal from the detector is proportional to the radiance from the atmosphere and window, because the reference radiance which is presented to the detector when the chopper interrupts the beam is less than 8K. Since the window is designed to operate cold (77K), the contribution from the window should be insignificant at the shorter wavelengths. At the longer wavelengths ($>15\mu m$) the window contribution has to be removed from the data. Since the window radiance is roughly gray body, removal of the window emission from the data is straightforward. However it seems the window did not cool to 77K and some window contribution is apparent in the data. At this time the window radiance has not been removed from either the short or long wavelength data.

Because of the dewar problems it was not possible to work extensively with the instrument before the balloon flight, so only one preflight calibration was performed. This calibration was performed using a blackbody source which could be cooled by liquid nitrogen to temperatures as low as 77 K. The blackbody used for this purpose could not be attached directly to the window mount. This presented a number of problems which are discussed in detail in the Results. The spectral scans of the blackbody obtained during this calibration were used to determine the appropriate calibration factors; and these calibration factors were used to reduce the data obtained during the flight. The wavelength calibration of the spectral data was accomplished by using known atmospheric emission lines that are present in the spectra obtained during the flight. The major emission features in both spectral regions are due to well known H_2O and CO_2 lines and offer a very convenient means of wavelength calibration.

Results

The data obtained during the balloon flight were initially reduced using the calibration factors determined from the preflight calibration. When these data were examined it was evident that the radiance values obtained were too high, indicating that the instrument was much more sensitive than the calibration had indicated. This was gratifying from an experimental standpoint, since it was anticipated that the instrument should be more sensitive than the preflight calibration had indicated. As mentioned in the discussion concerning the calibration, it was not possible at that time to seal the calibration blackbody onto the spectrometer and, as a result, the possibility existed that frost could form on the window. A thin layer of frost could significantly attenuate the radiation from the blackbody with a resulting loss in apparent sensitivity. A blackbody system was later constructed which fits directly to the window mount and insures that the window remains frost free. Calibration runs made with this system indicate a system sensitivity close to that which appears necessary for the balloon

flight results to be physically reasonable. Therefore, the data have been reduced using these calibration factors rather than the earlier data. The accuracy of the results have been checked by comparing the emission at 12.6μm due to CO_2. The accuracy with which this emission can be determined theoretically is not well established, since it represents an absorption of less than 1% and most models have not been checked down to these low levels. In view of these calibration uncertainties the data must be considered provisional. The instrument was flown again on 19 February 1975 and these data along with the additional calibrations and experiences with the system should allow a better assessment of the accuracy of the data presented here.

The spectra obtained at several altitudes and at several different elevation angles are given in Figures 1 through 59. The short wavelength (8.5μm to 13.3μm) spectra are shown in Figures 1 through 15 and the long wavelength (19.0μm to 26.0μm) spectra are shown in Figures 16 through 59. Several consecutive records are co-added for each figure, as is indicated in the figure legends. The altitudes and times shown are those half-way through the co-added records for each figure.

Acknowledgments

The launch and recovery of the balloon instrumentation was capably handled by the Air Force Cambridge Research Laboratories Balloon Group. Financial support of Ballistics Research Laboratories for construction of the instrument is acknowledged.

Acknowledgment is made to the National Center for Atmospheric Research, which is sponsored by the National Science Foundation, for computer time used in this research. Thanks are also due to John Van Allen for data reduction and plotting and to Carolyn Bauer for report preparation.

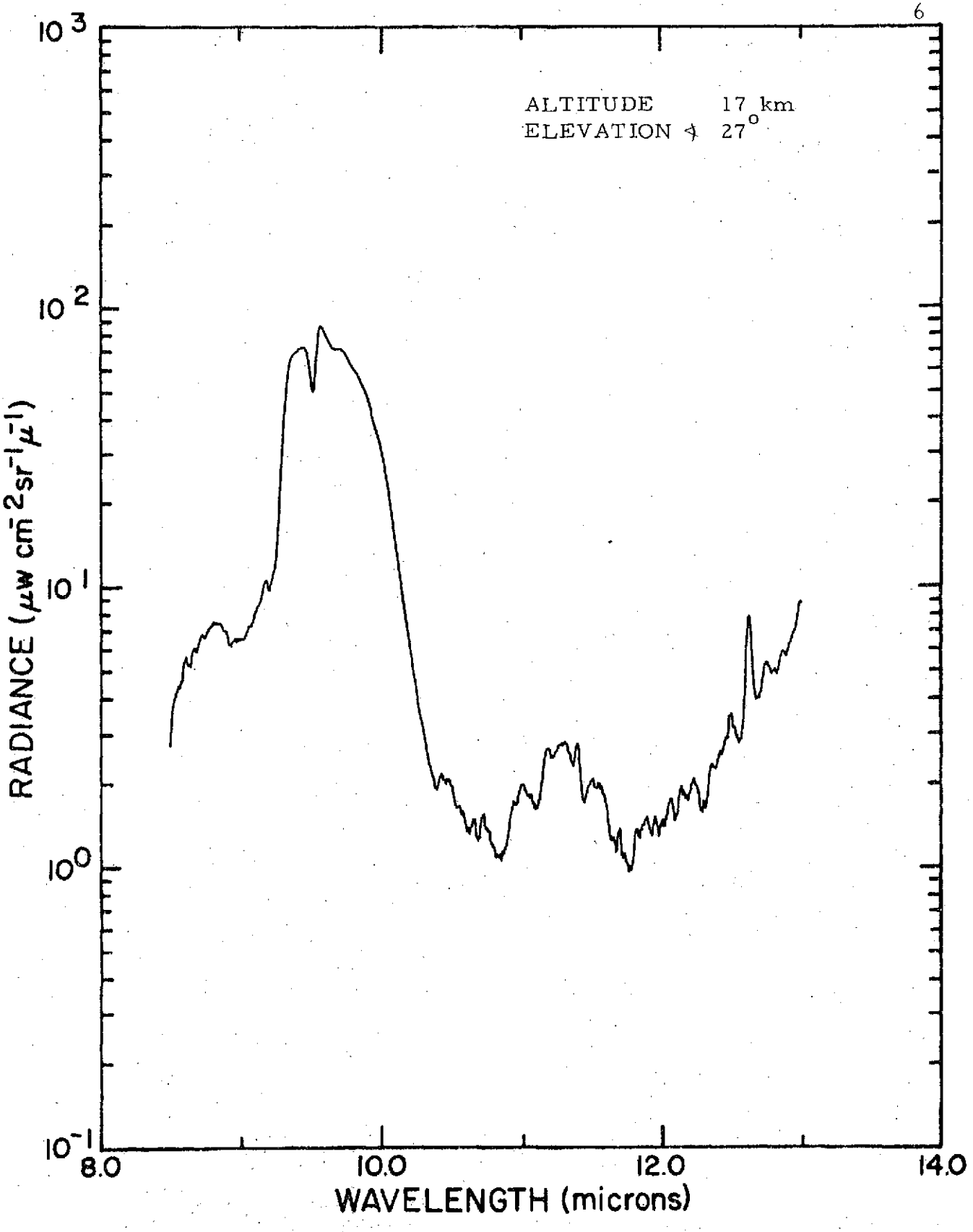

Figure 1. Radiance vs Wavelength for 27 June 1974 flight. Records 88-94 are co-added and time is 0805 MDT.

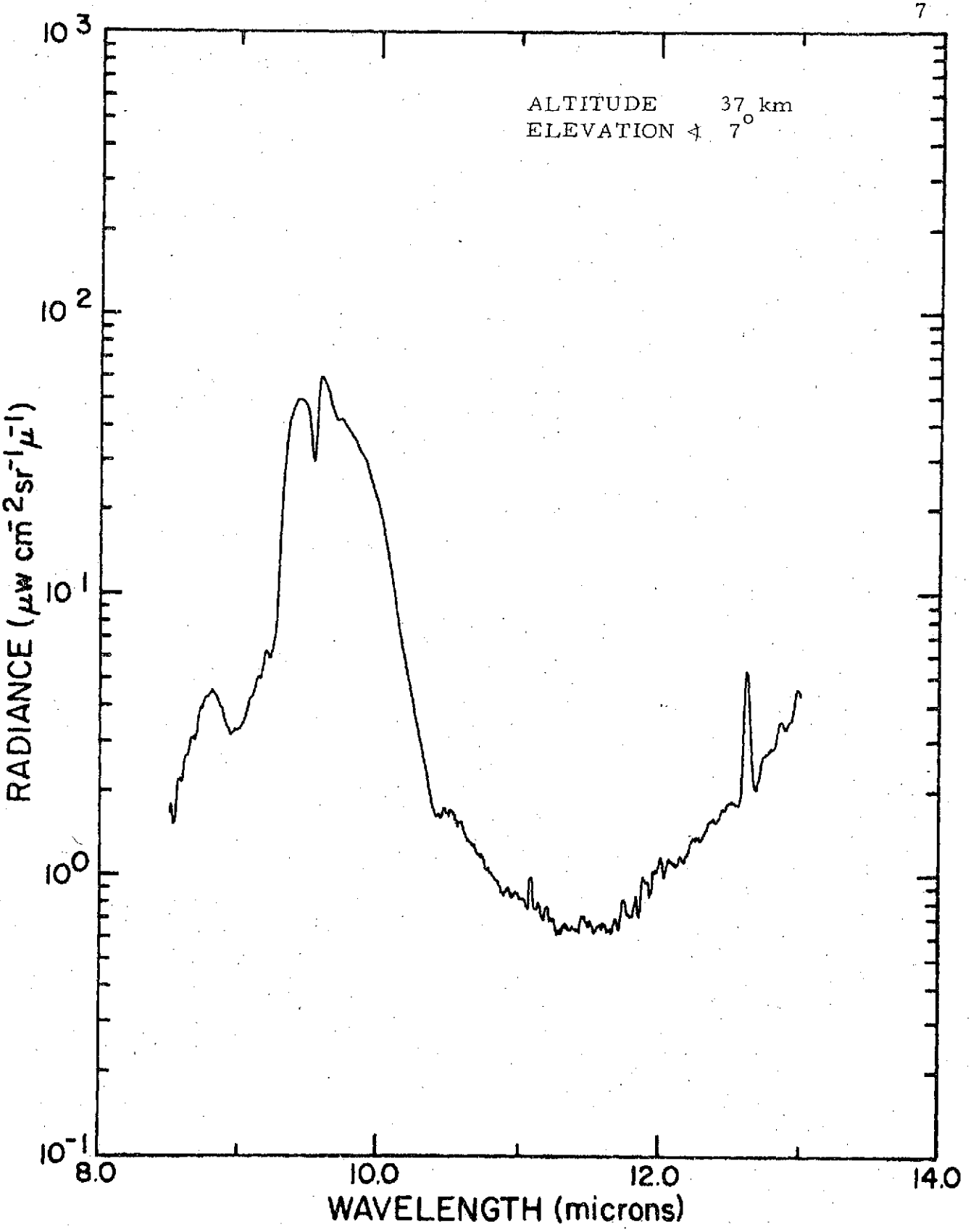

Figure 2. Radiance vs Wavelength for 27 June 1974 flight. Records 192-204 are co-added and time is 0924 MDT.

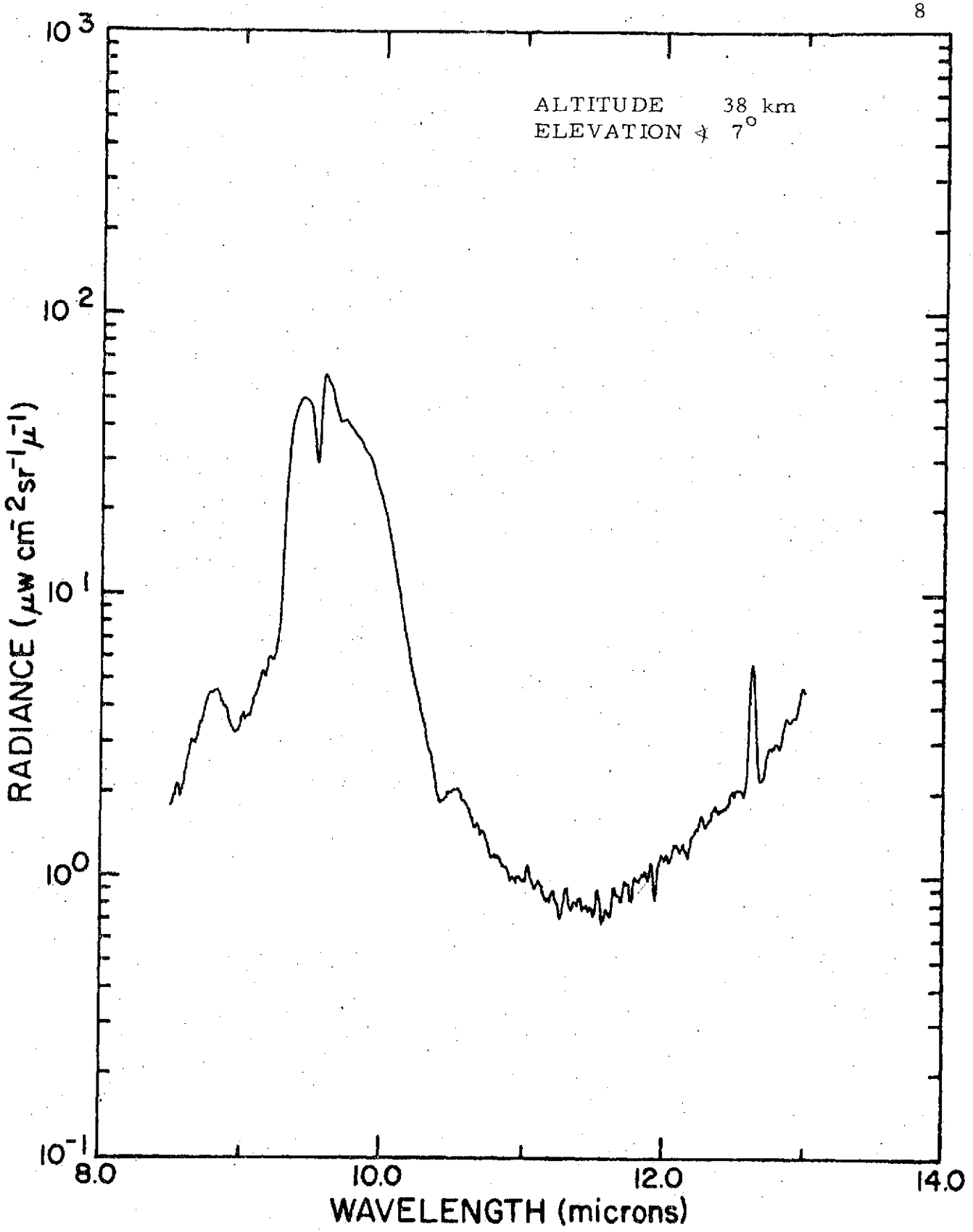

Figure 3. Radiance vs Wavelength for 27 June 1974 flight. Records 205-212 and 219-226 are co-added and time is 0936 MDT.

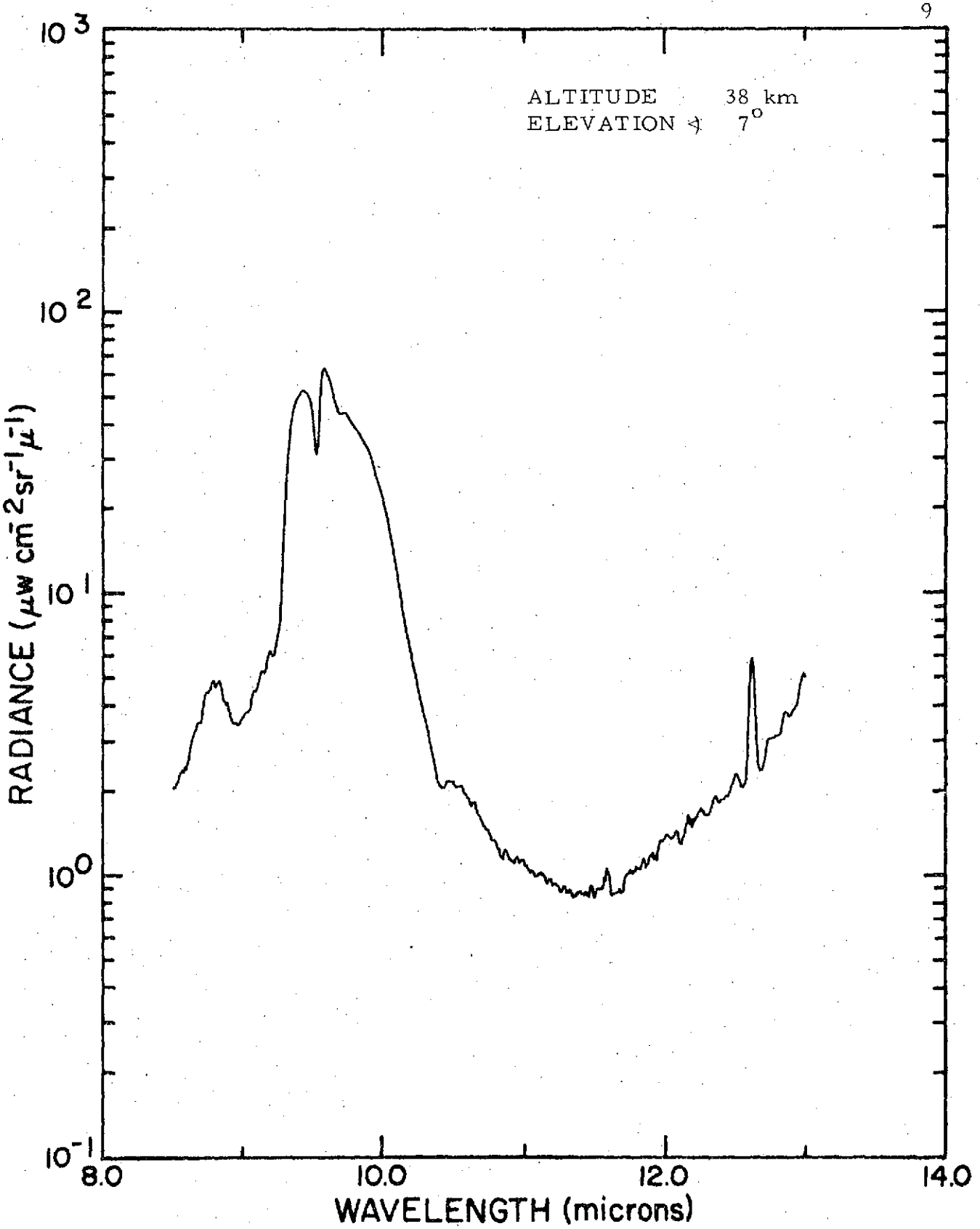

Figure 4. Radiance vs Wavelength for 27 June 1974 flight. Records 227-247 are co-added and time is 0951 MDT.

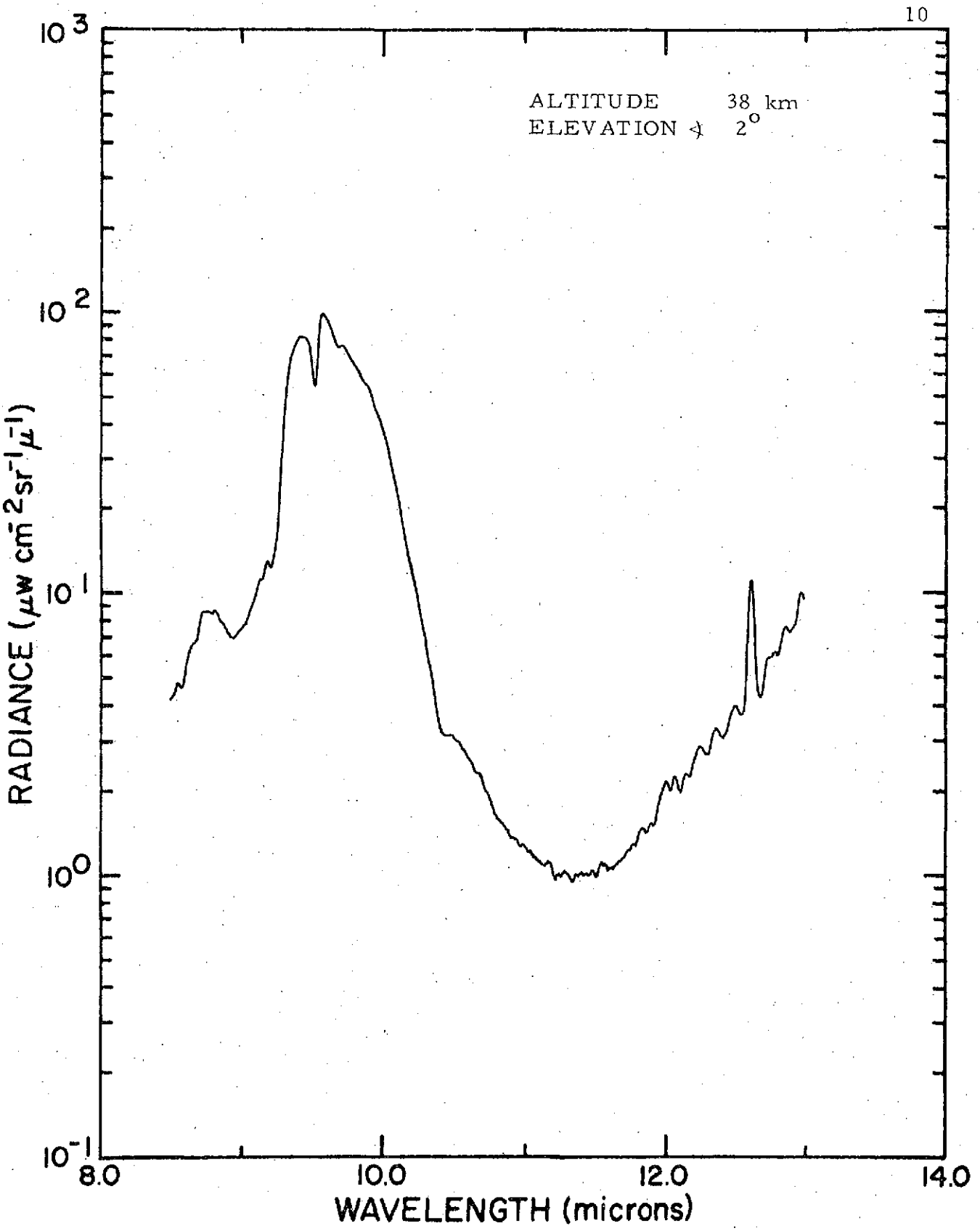

Figure 5. Radiance vs Wavelength for 27 June 1974 flight. Records 250-259 and 261-275 are co-added and time is 1010 MDT.

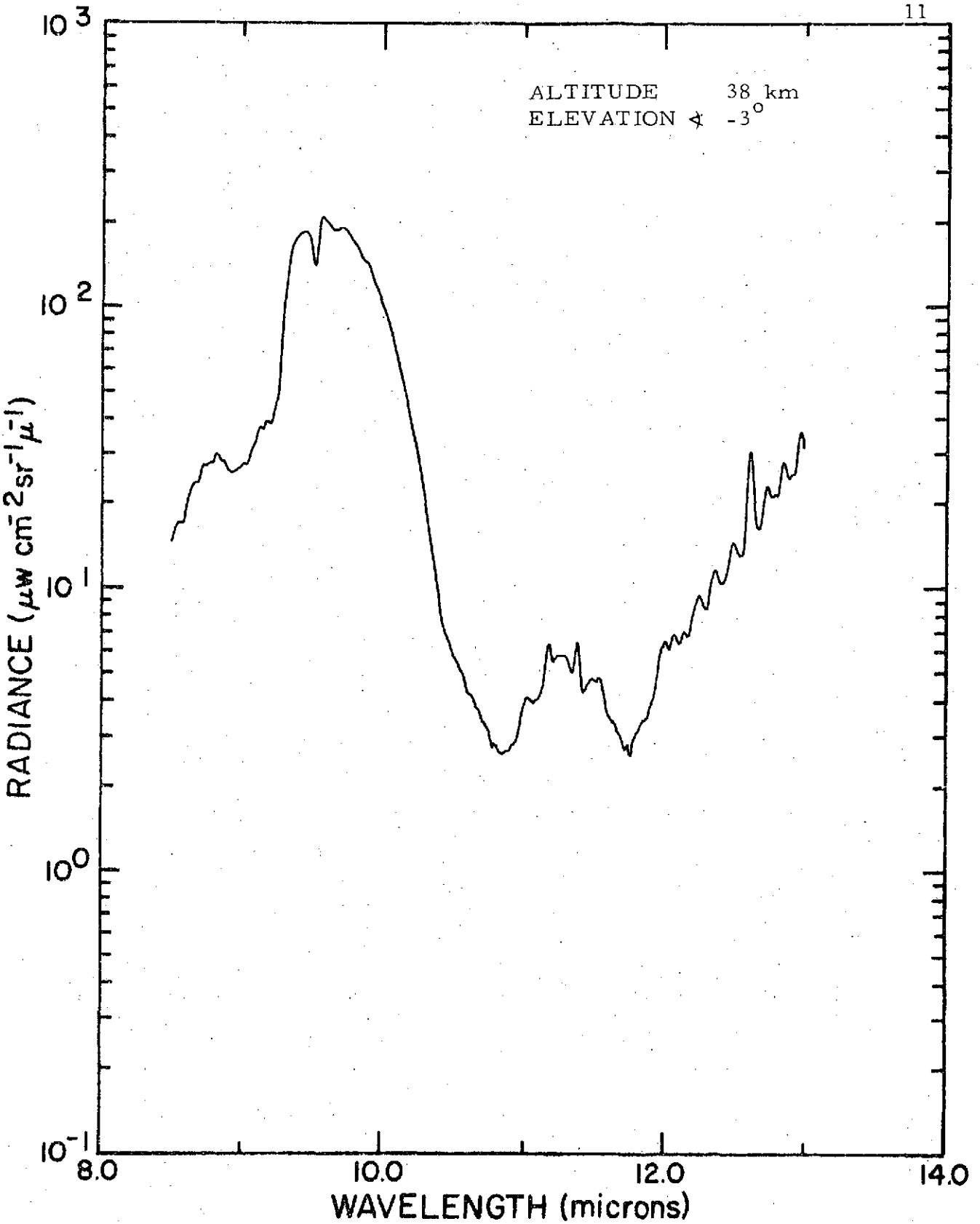

Figure 6. Radiance vs Wavelength for 27 June 1974 flight. Records 278-280 are co-added and time is 1021 MDT.

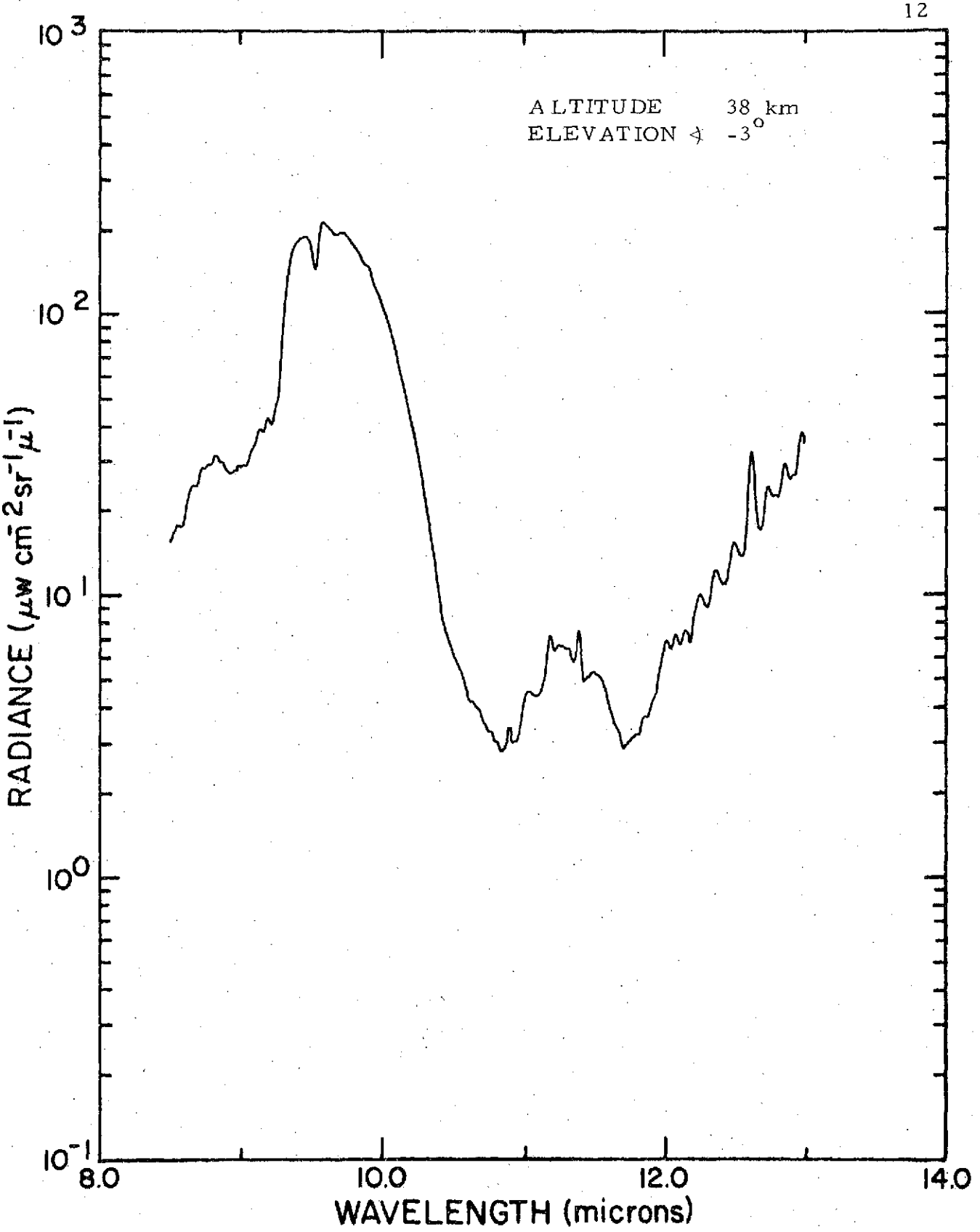

Figure 7. Radiance vs Wavelength for 27 June 1974 flight. Records 284-286 are co-added and time is 1025 MDT.

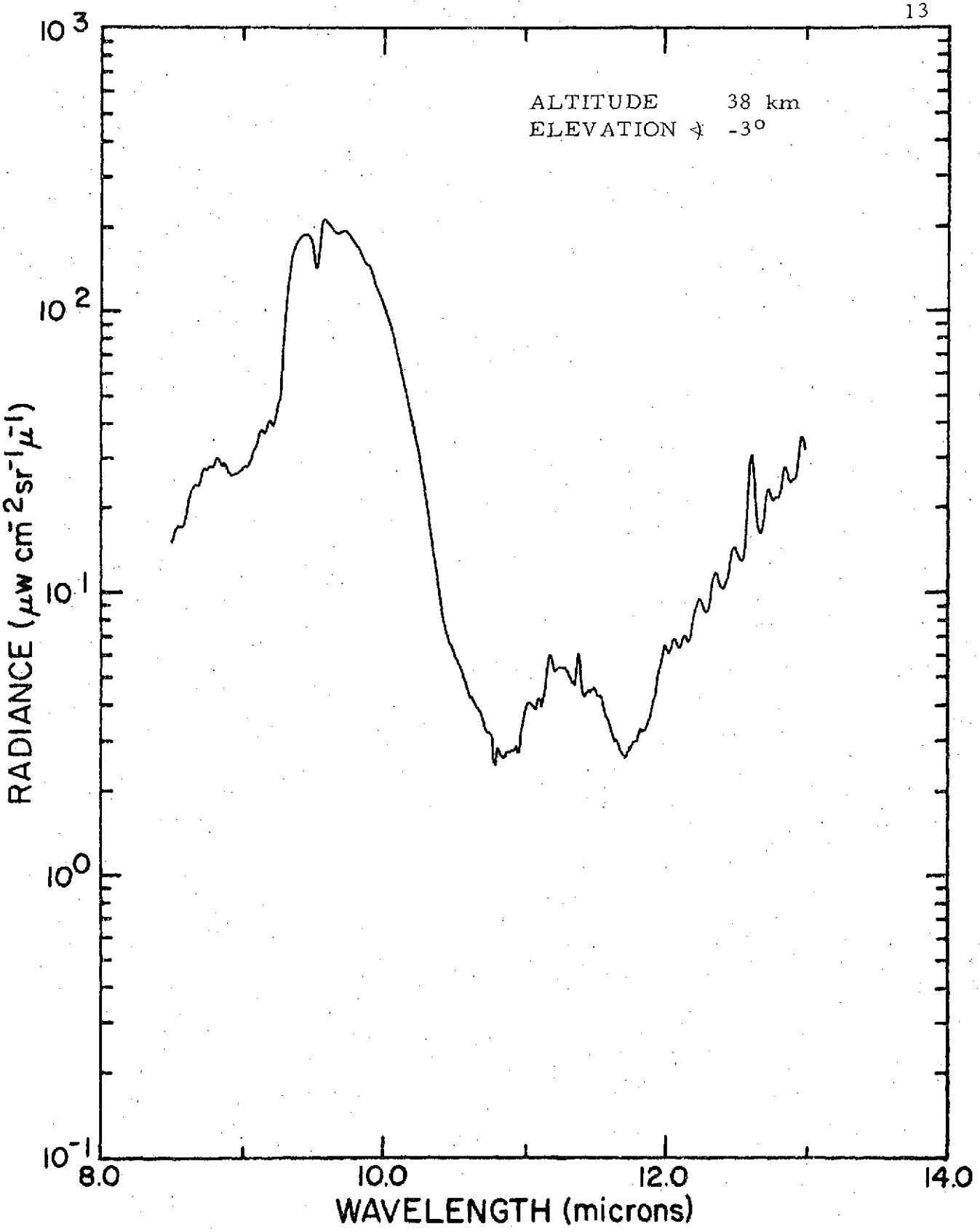

Figure 8. Radiance vs Wavelength for 27 June 1974 flight. Records 287-289 are co-added and time is 1027 MDT.

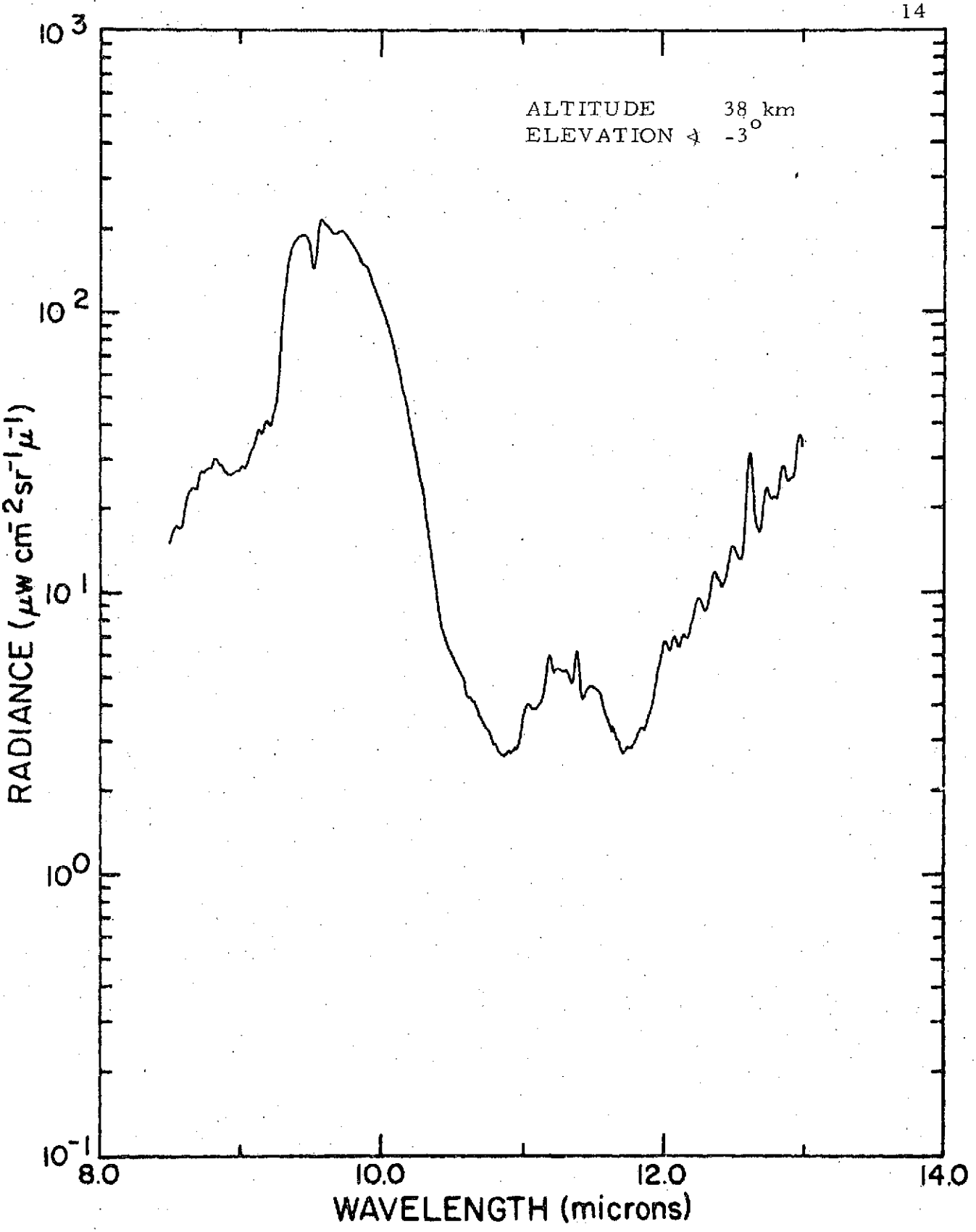

Figure 9. Radiance vs Wavelength for 27 June 1974 flight. Records 290-292 are co-added and time is 1030 MDT.

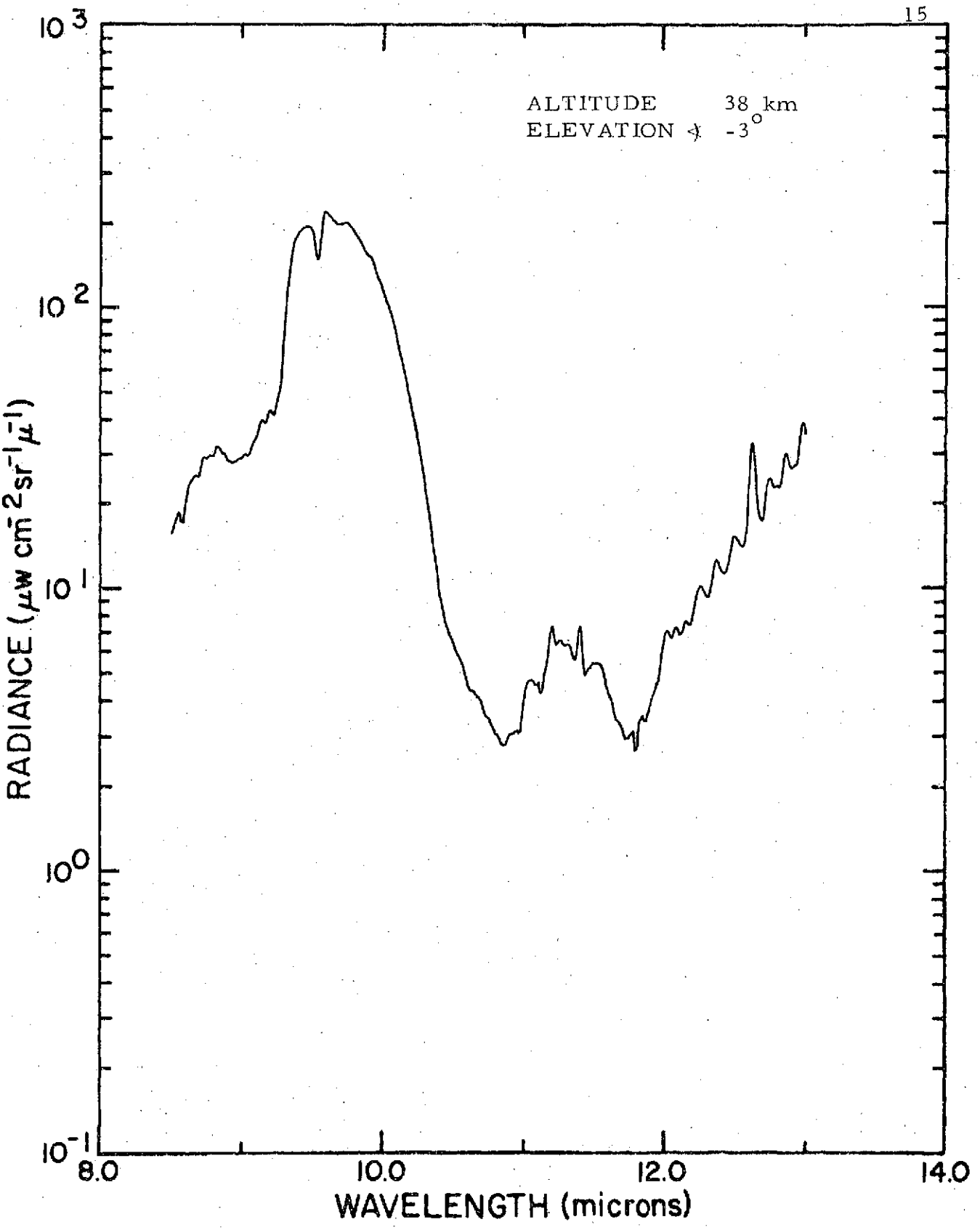

Figure 10. Radiance vs Wavelength for 27 June 1974 flight. Records 293-295 are co-added and time is 1032 MDT.

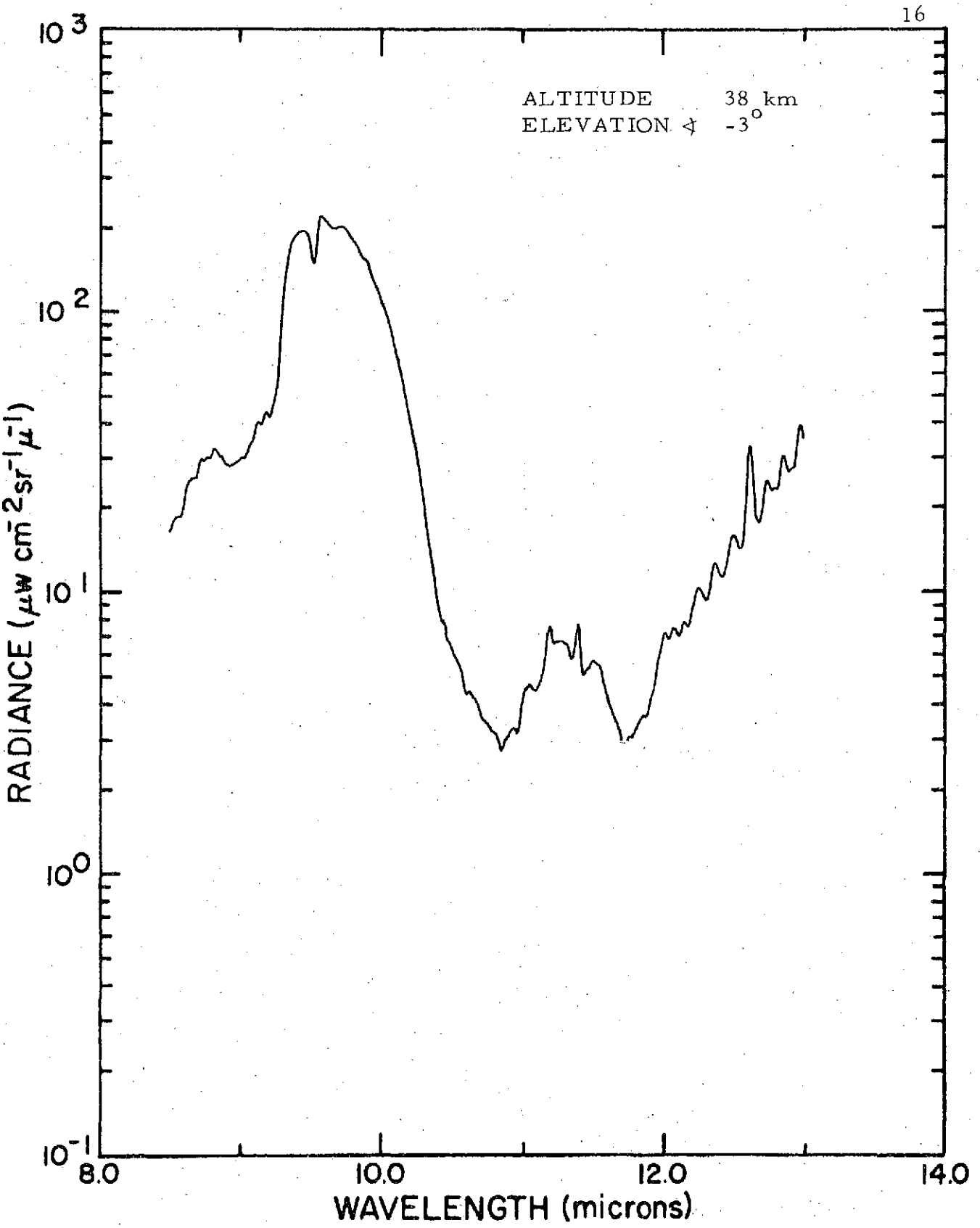

Figure 11. Radiance vs Wavelength for 27 June 1974 flight. Records 296-298 are co-added and time is 1034 MDT.

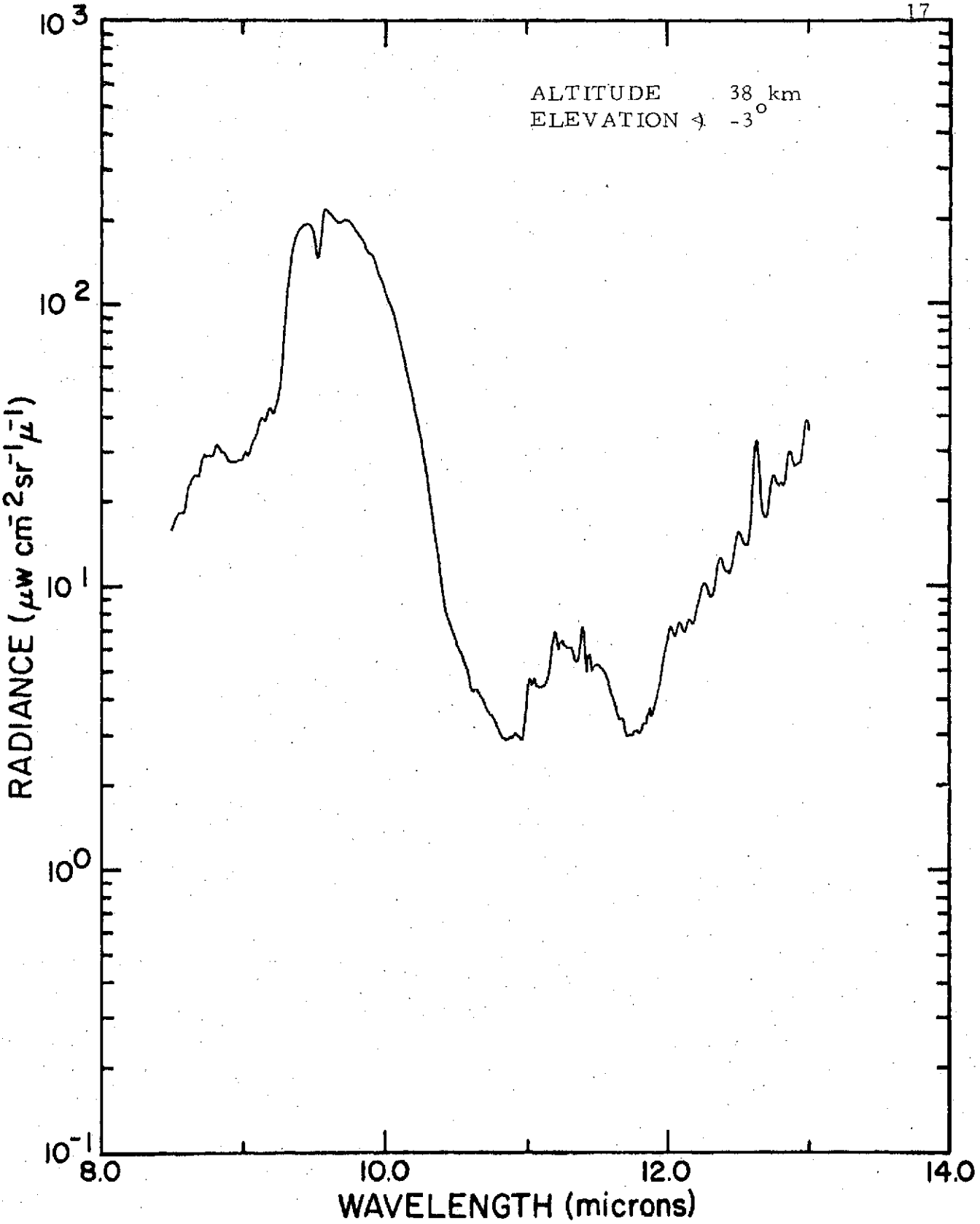

Figure 12. Radiance vs Wavelength for 27 June 1974 flight. Records 302-304 are co-added and time is 1038 MDT.

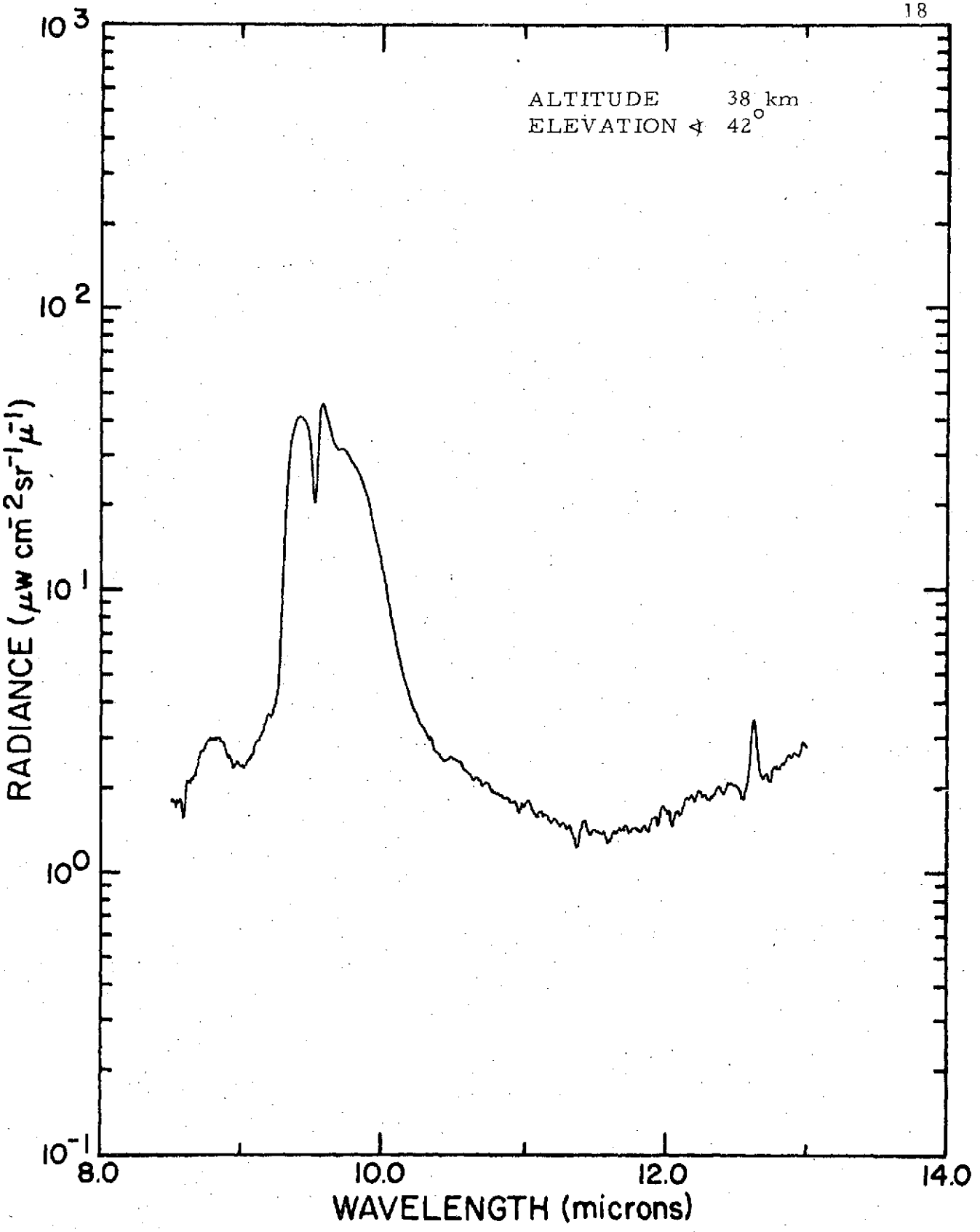

Figure 13. Radiance vs Wavelength for 27 June 1974 flight. Records 308, 309 and 311-318 are co-added and time is 1045 MDT.

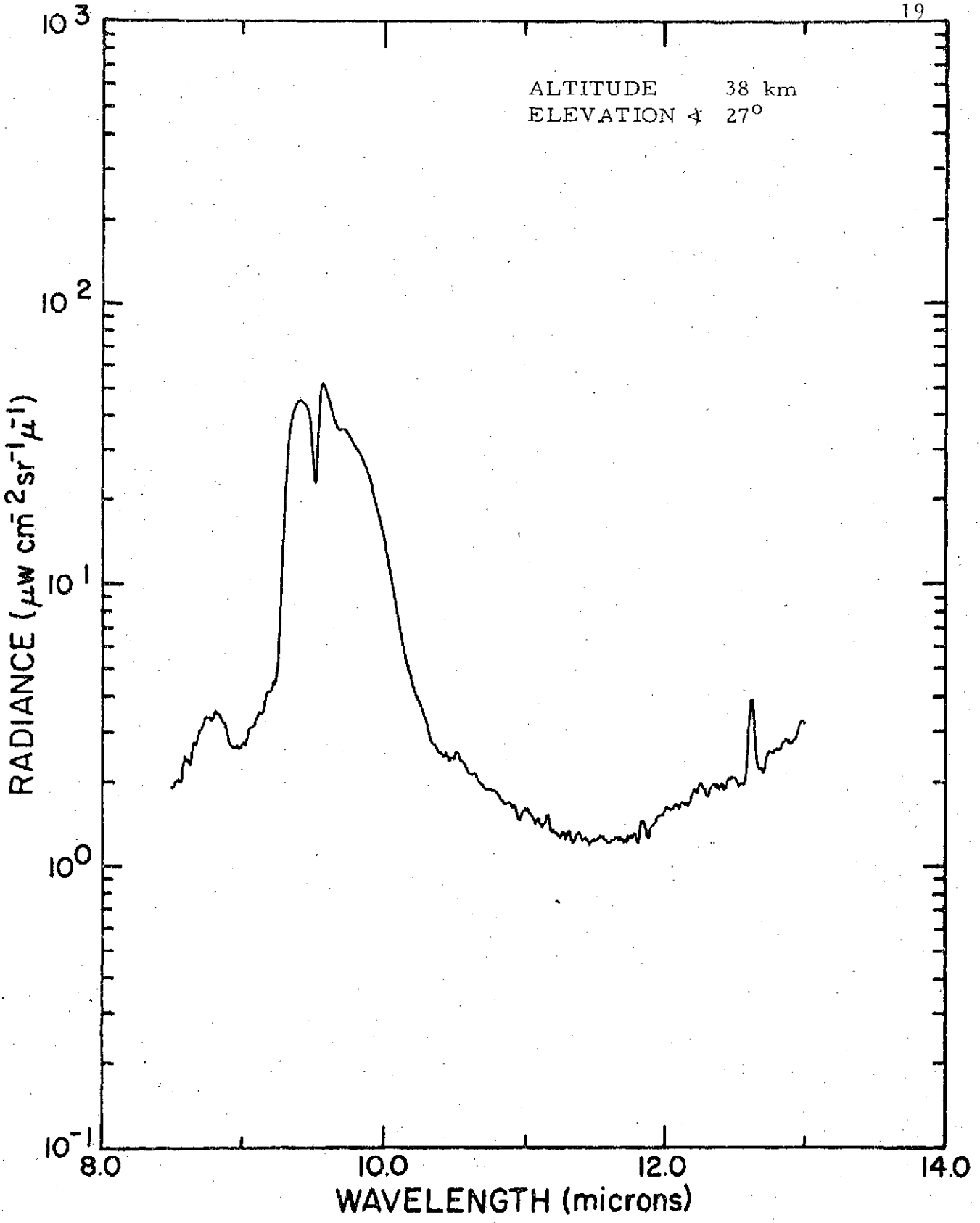

Figure 14. Radiance vs Wavelength for 27 June 1974 flight. Records 322, 323, 325, 326, 328-330, 333-338, 340-342, 345 and 346 are co-added and time is 1104 MDT.

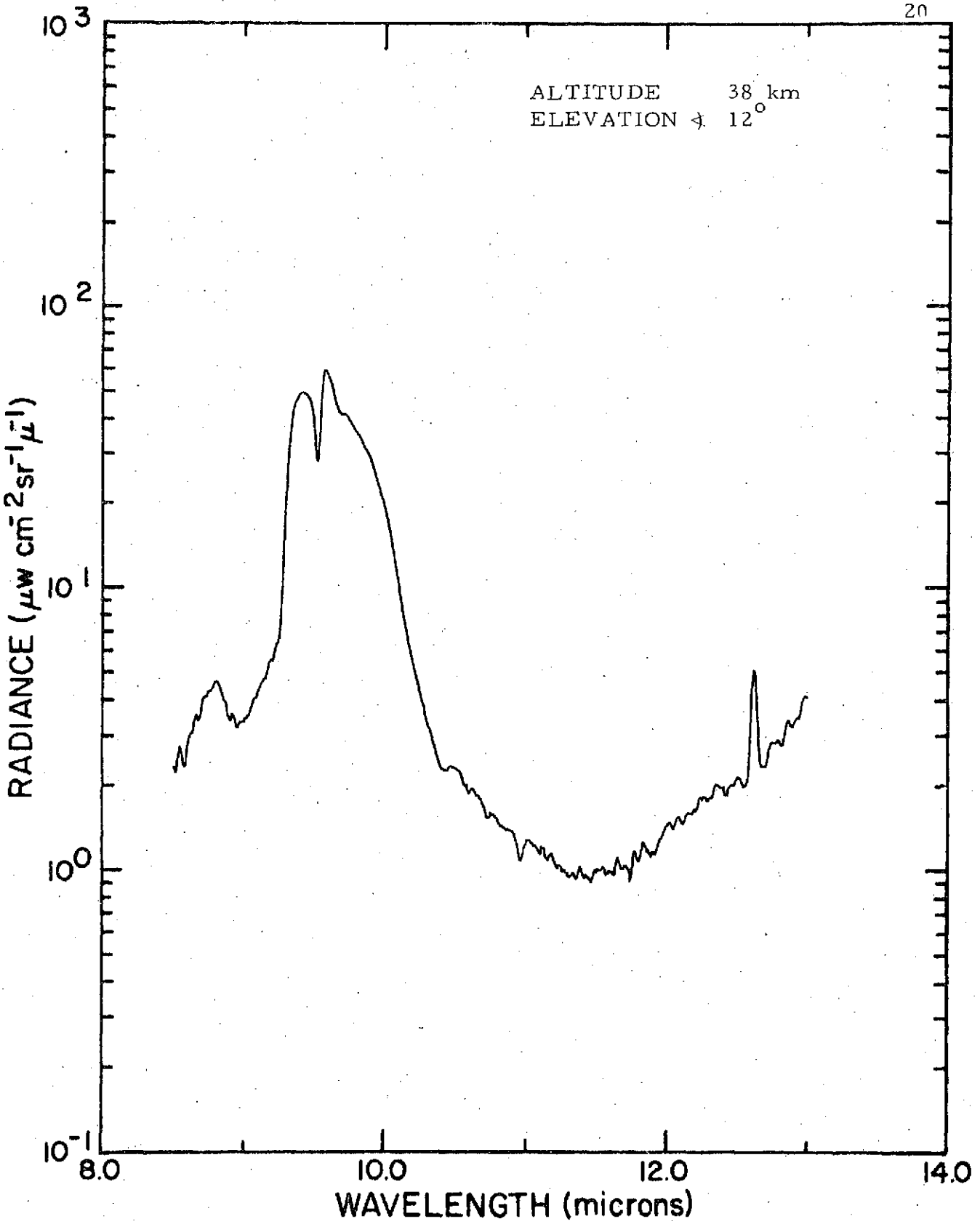

Figure 15. Radiance vs Wavelength for 27 June 1974 flight. Records 349-361 are co-added and time is 1115 MDT.

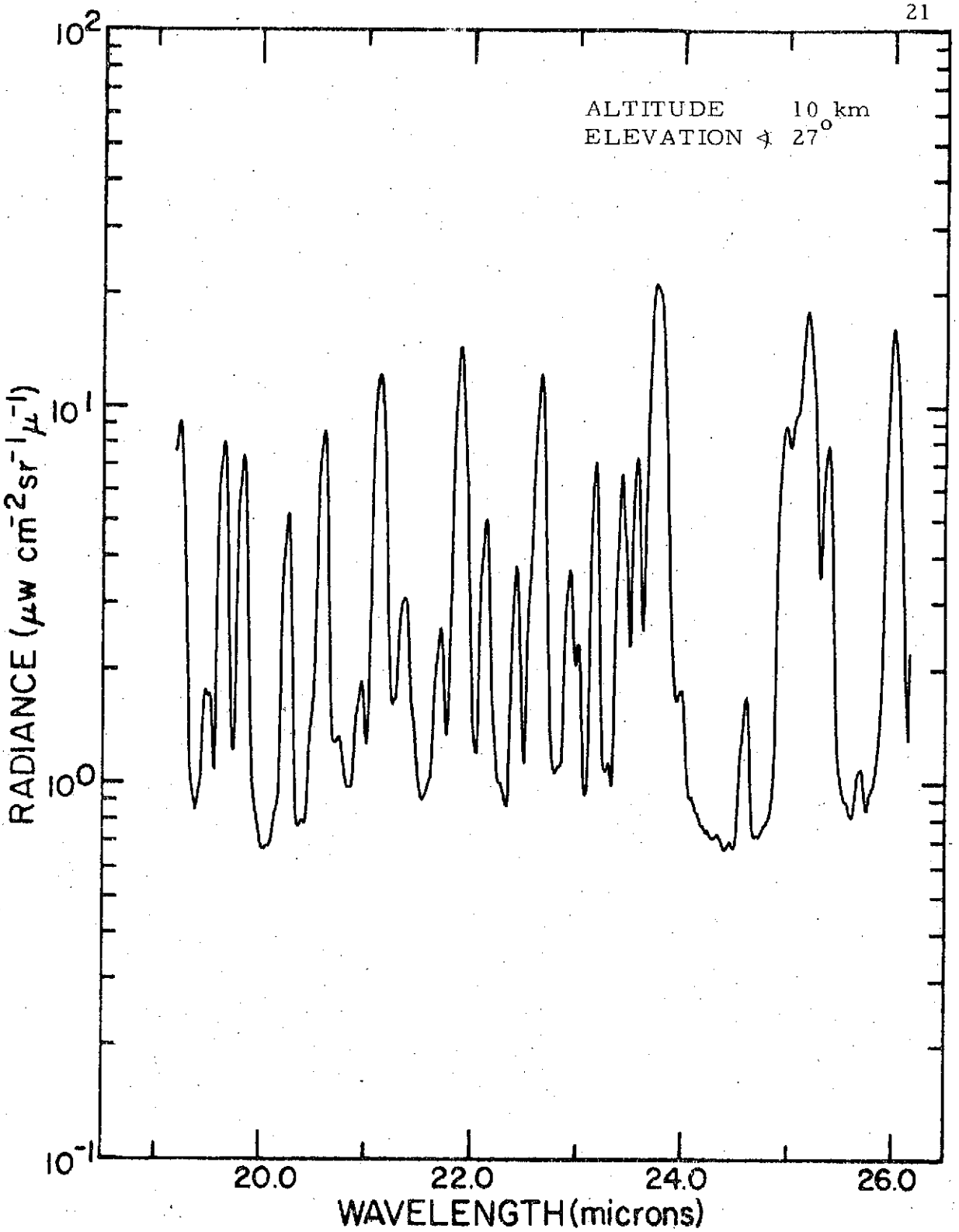

Figure 16. Radiance vs Wavelength for 27 June 1974 flight. Records 56, 57, 59 and 60 are co-added and time is 0740 MDT.

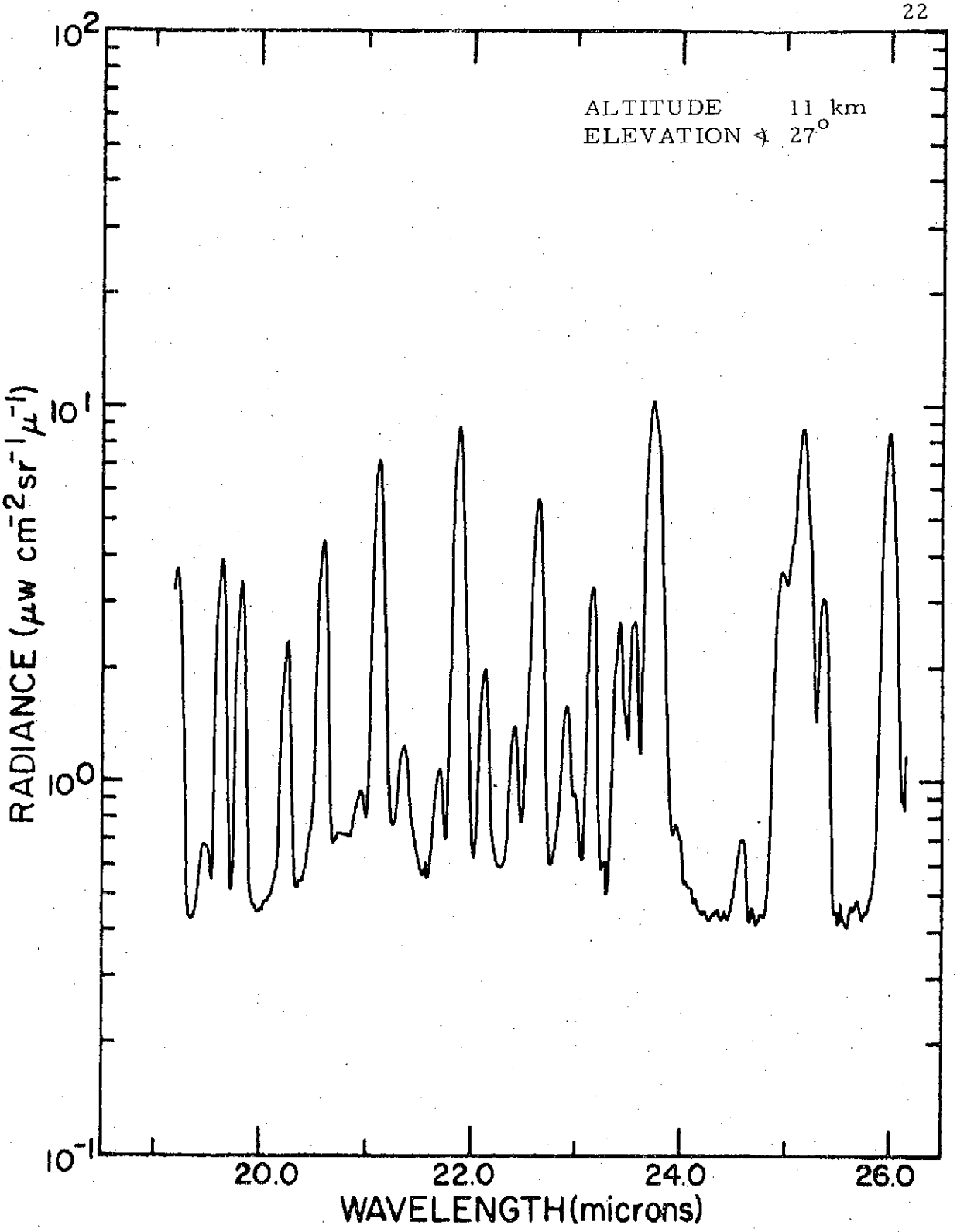

Figure 17. Radiance vs Wavelength for 27 June 1974 flight. Records 61-64 are co-added and time is 0743 MDT.

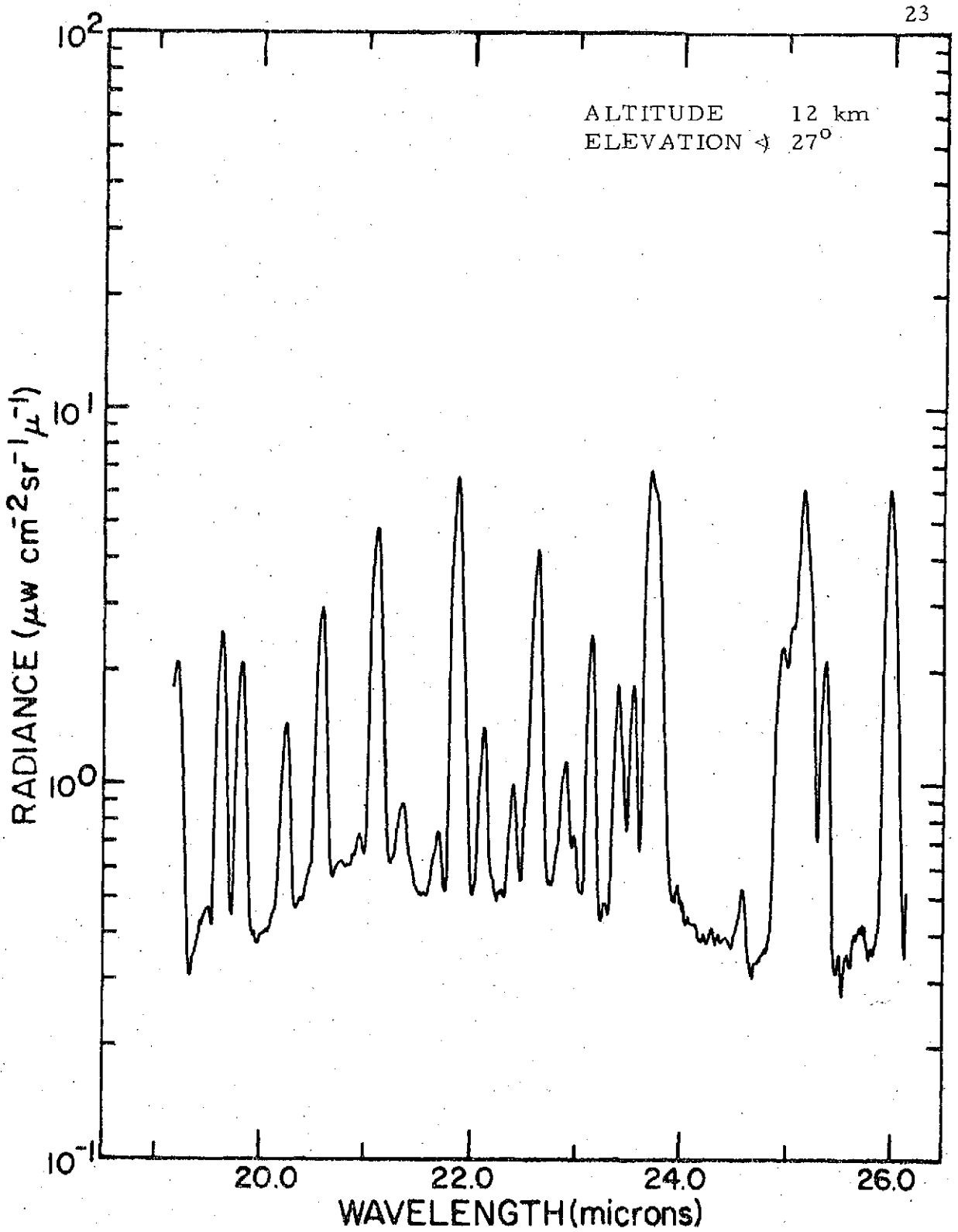

Figure 18. Radiance vs Wavelength for 27 June 1974 flight. Records 66-69 are co-added and time is 0747 MDT.

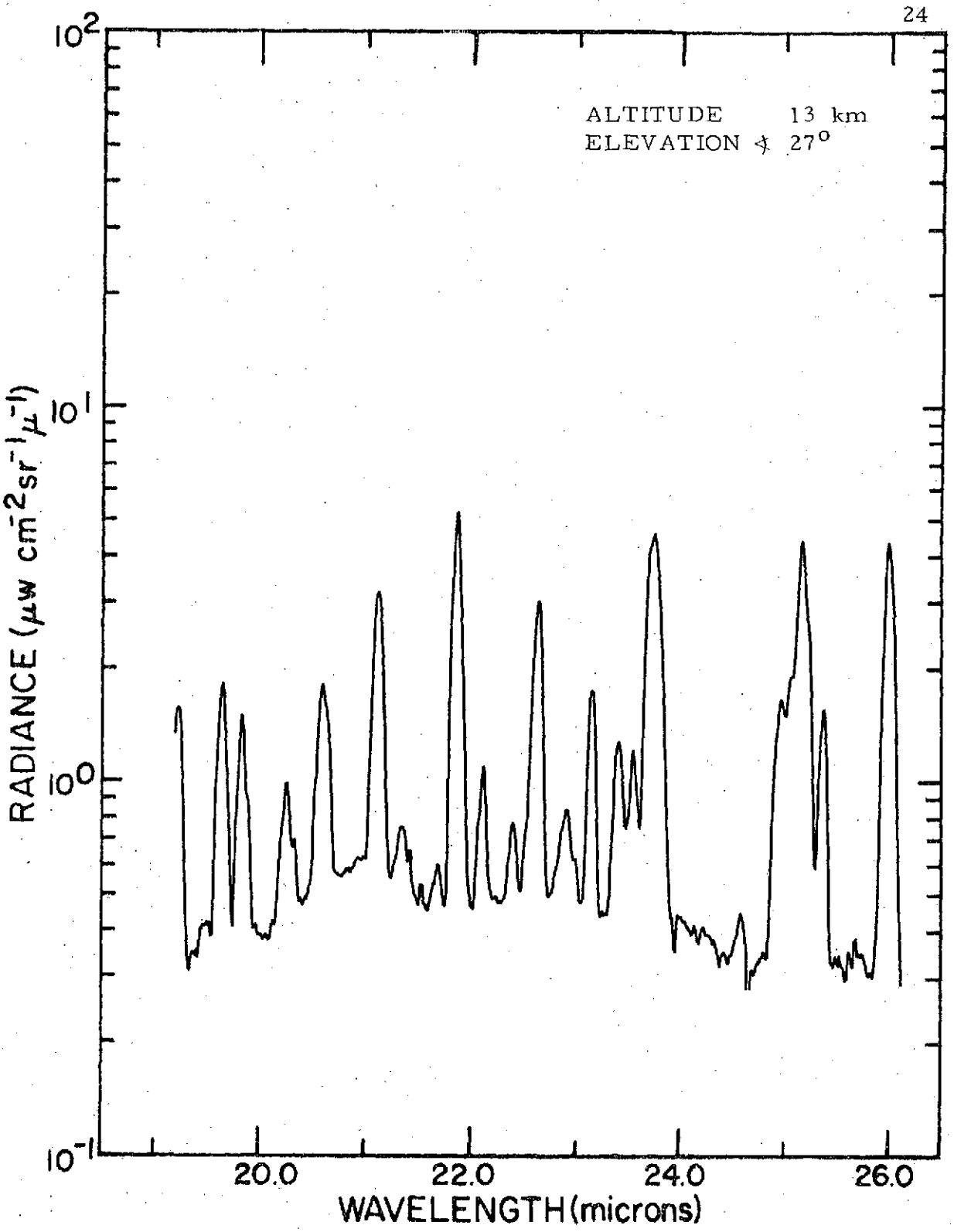

Figure 19. Radiance vs Wavelength for 27 June 1974 flight. Records 71-73 are co-added and time is 0751 MDT.

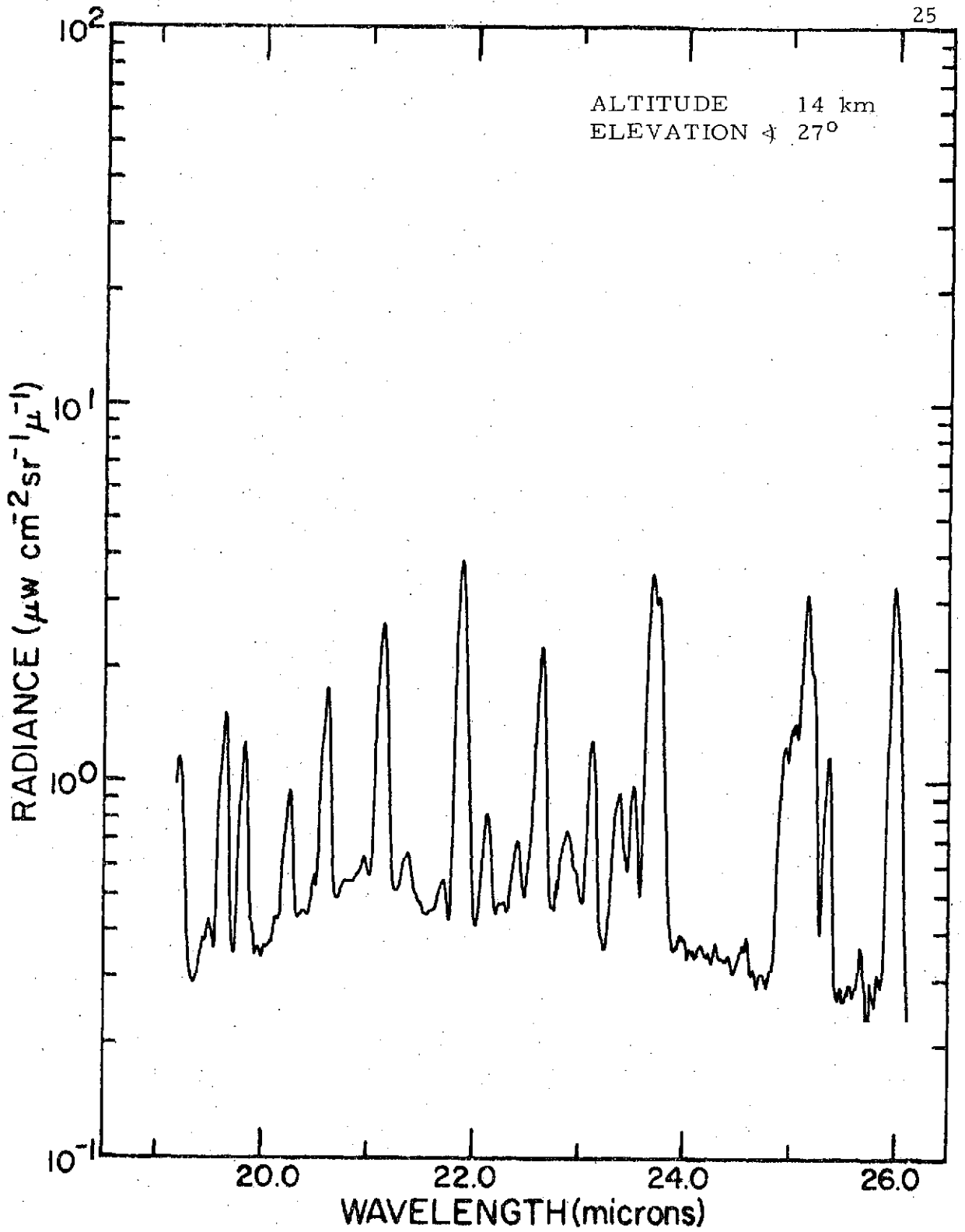

Figure 20. Radiance vs Wavelength for 27 June 1974 flight. Records 74-78 are co-added and time is 0753.

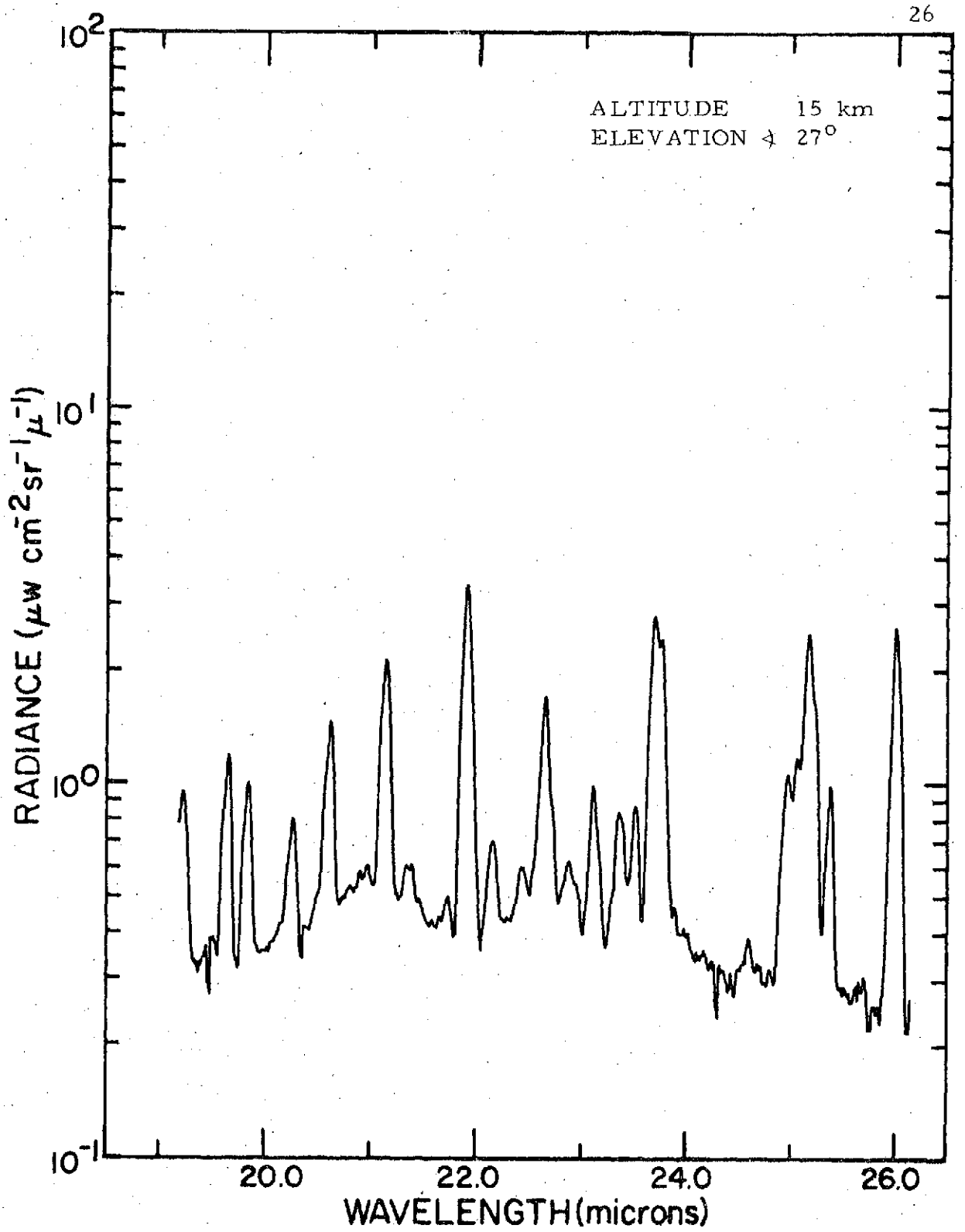

Figure 21. Radiance vs Wavelength for 27 June 1974 flight. Records 79-82 are co-added and time is 0757 MDT.

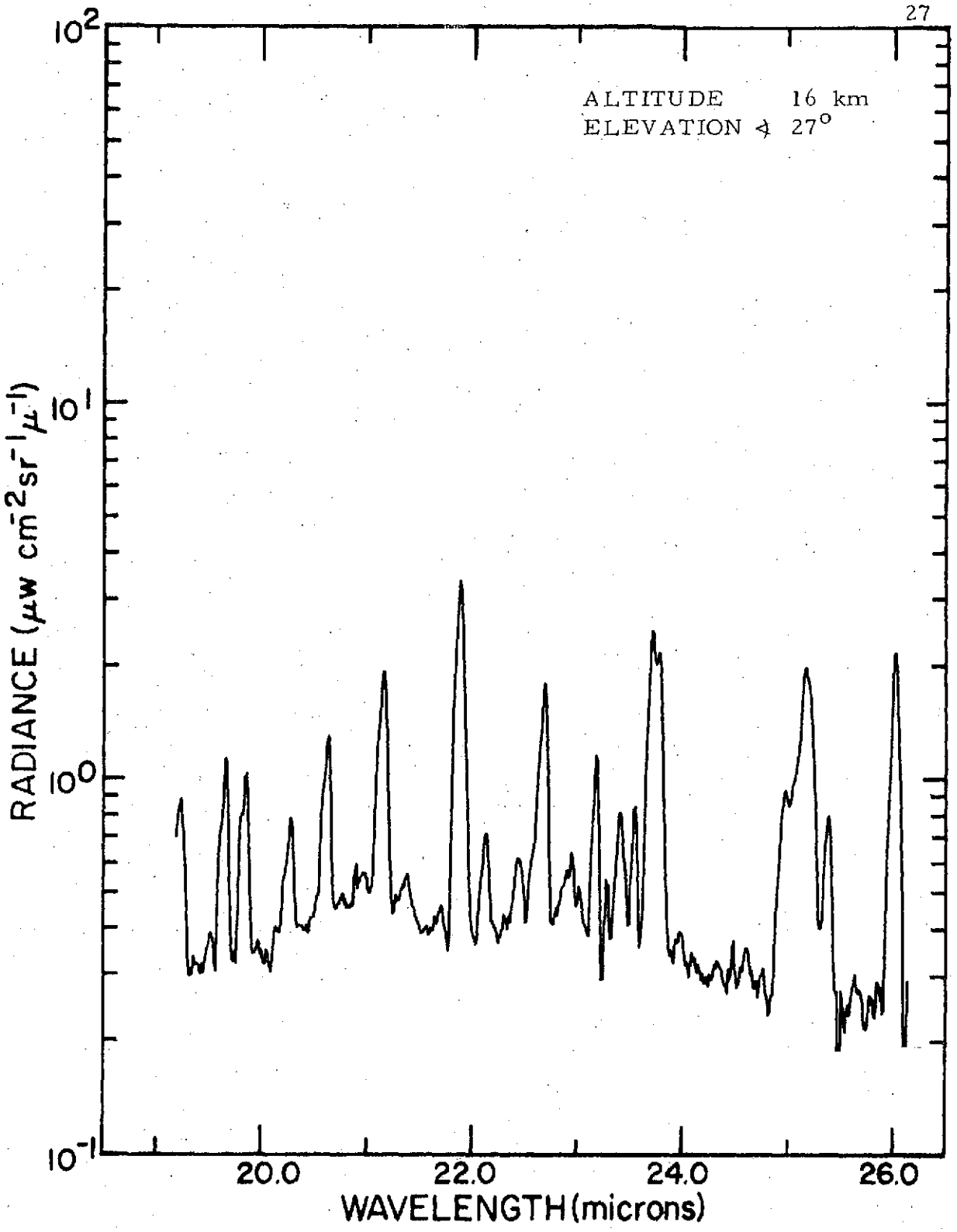

Figure 22. Radiance vs Wavelength for 27 June 1974 flight. Records 85 and 86 are co-added and time is 0800 MDT.

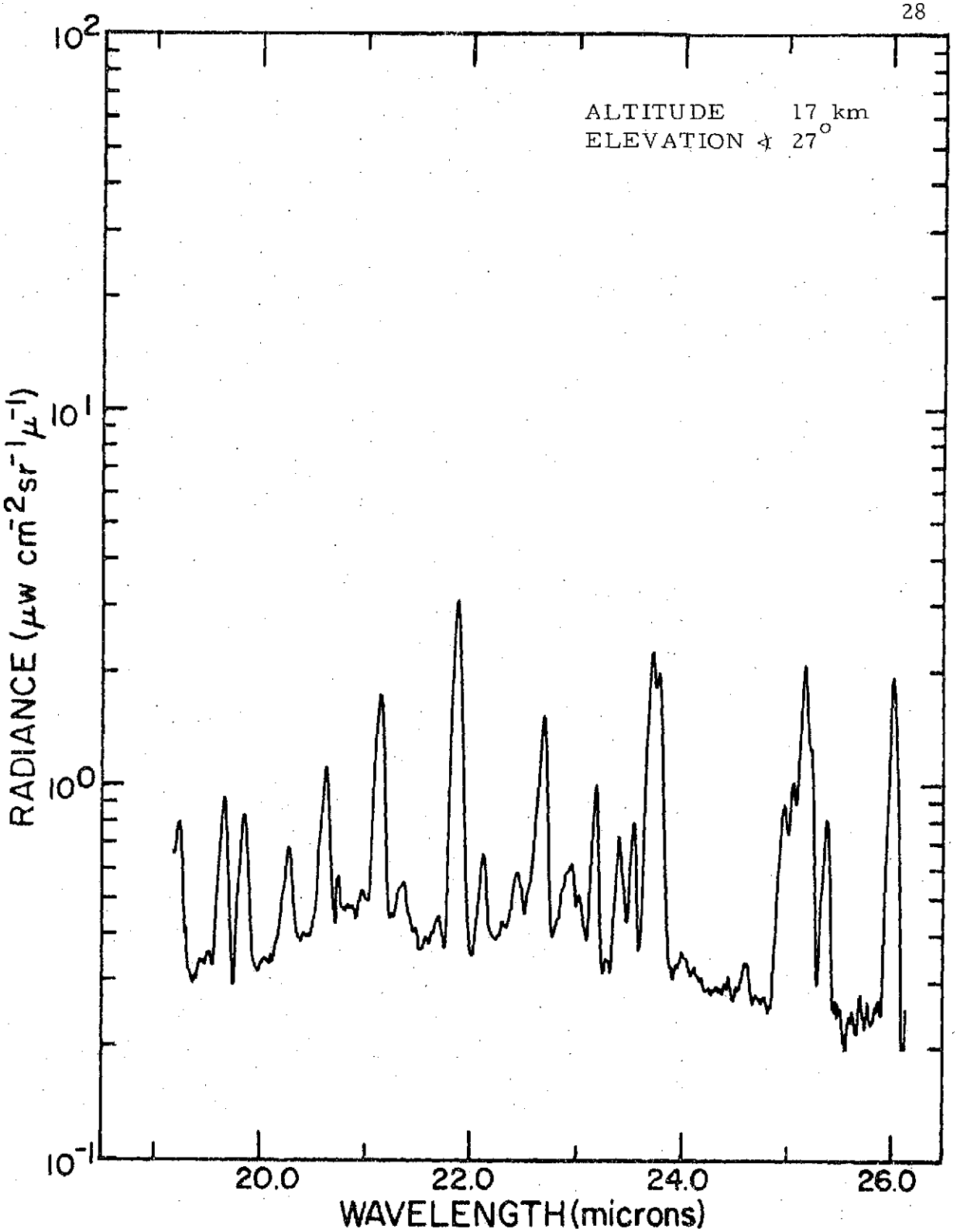

Figure 23. Radiance vs Wavelength for 27 June 1974 flight. Records 88-94 are co-added and time is 0805 MDT.

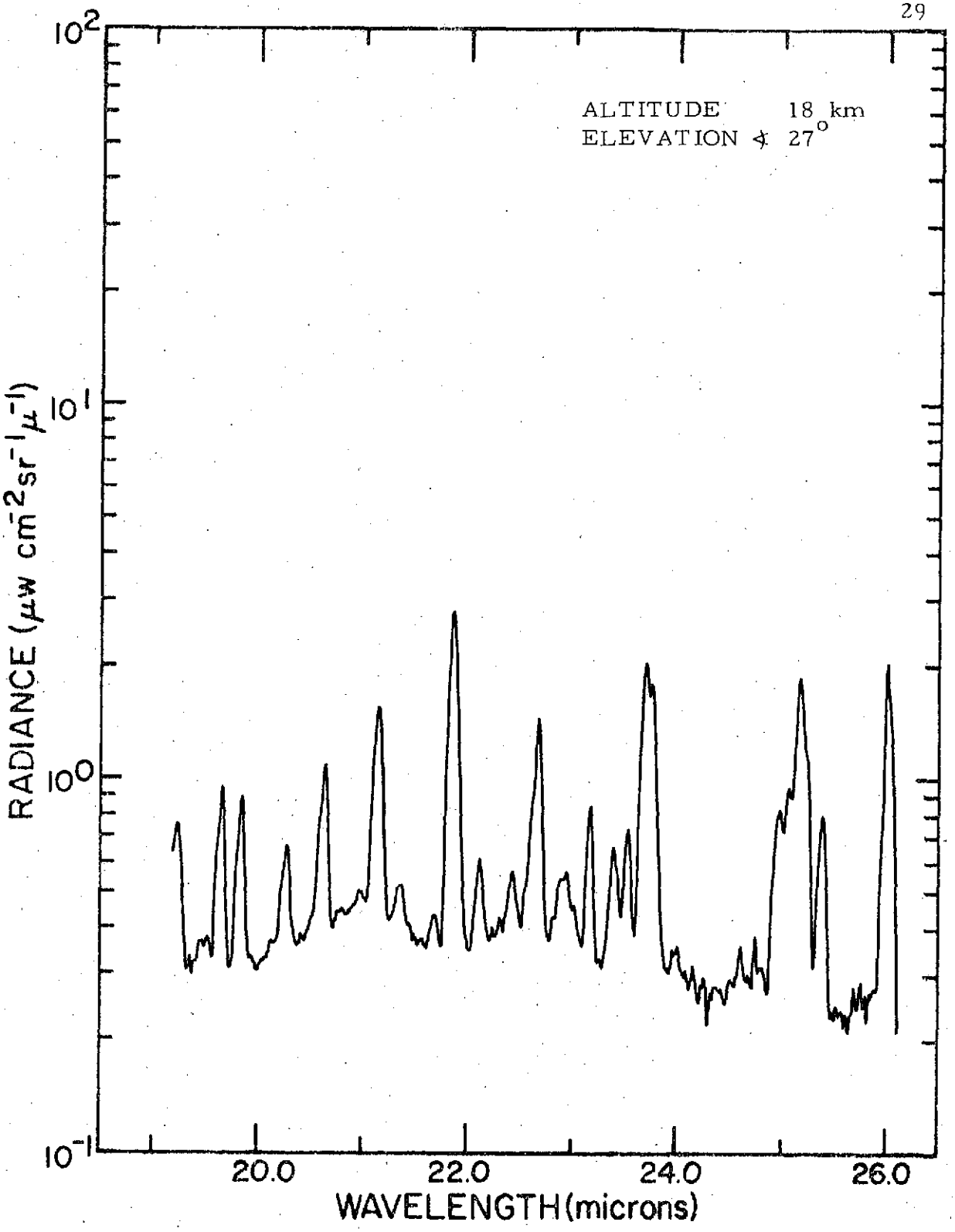

Figure 24. Radiance vs Wavelength for 27 June 1974 flight. Records 96-102 are co-added and time is 0811 MDT.

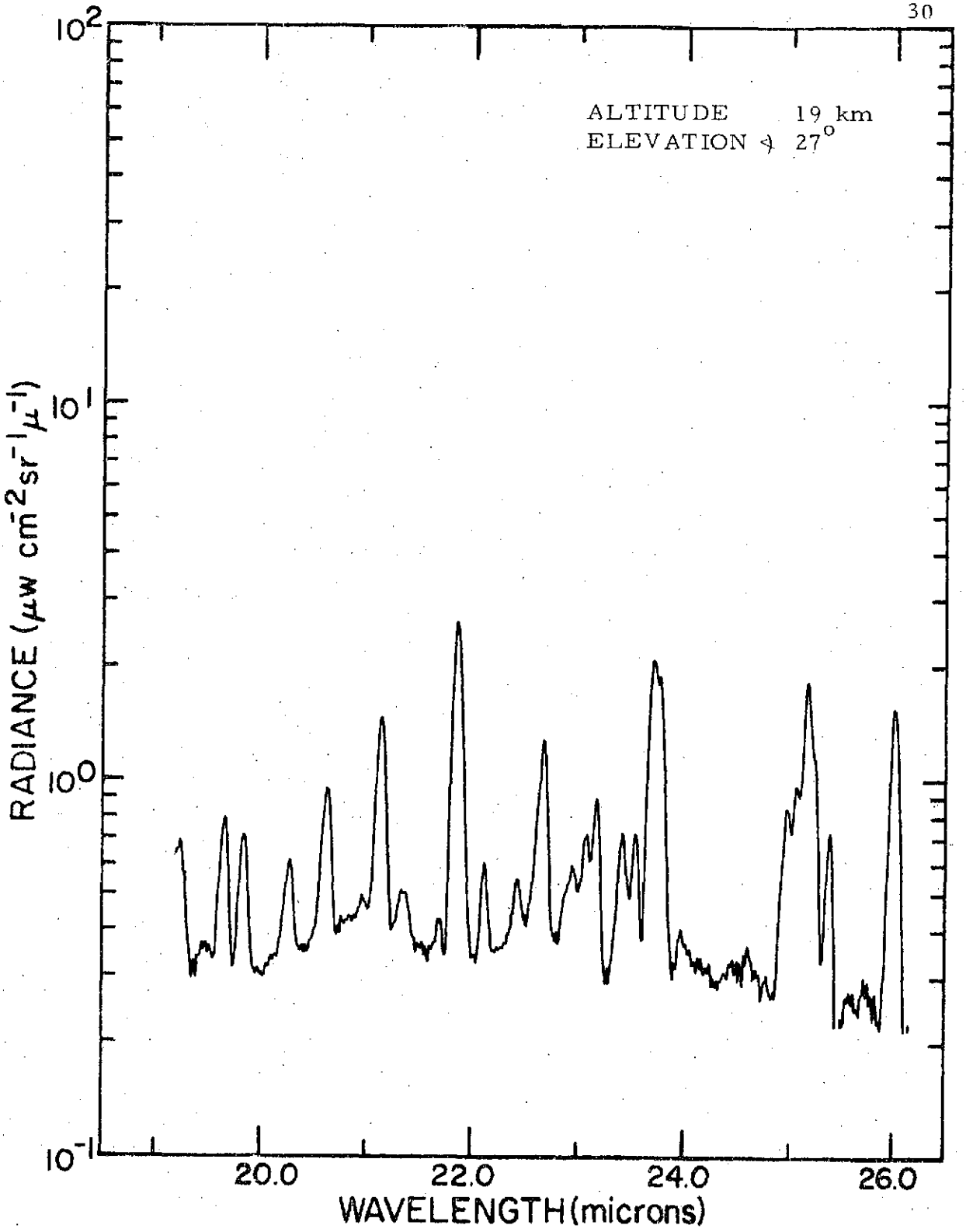

Figure 25. Radiance vs Wavelength for 27 June 1974 flight. Records 103 and 105 are co-added and time is 0814 MDT.

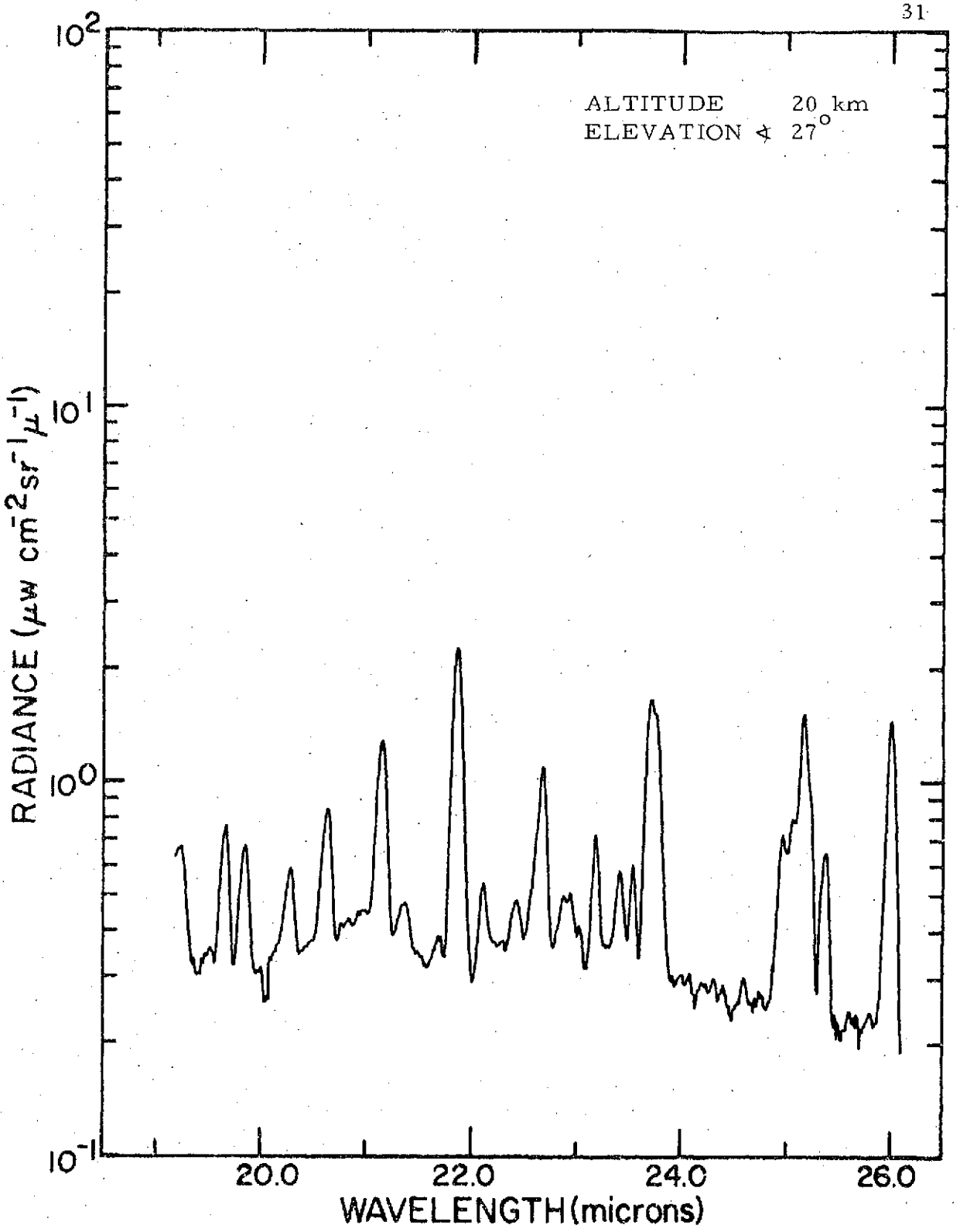

Figure 26. Radiance vs Wavelength for 27 June 1974 flight. Records 107, 108, 110 and 111 are co-added and time is 0819 MDT.

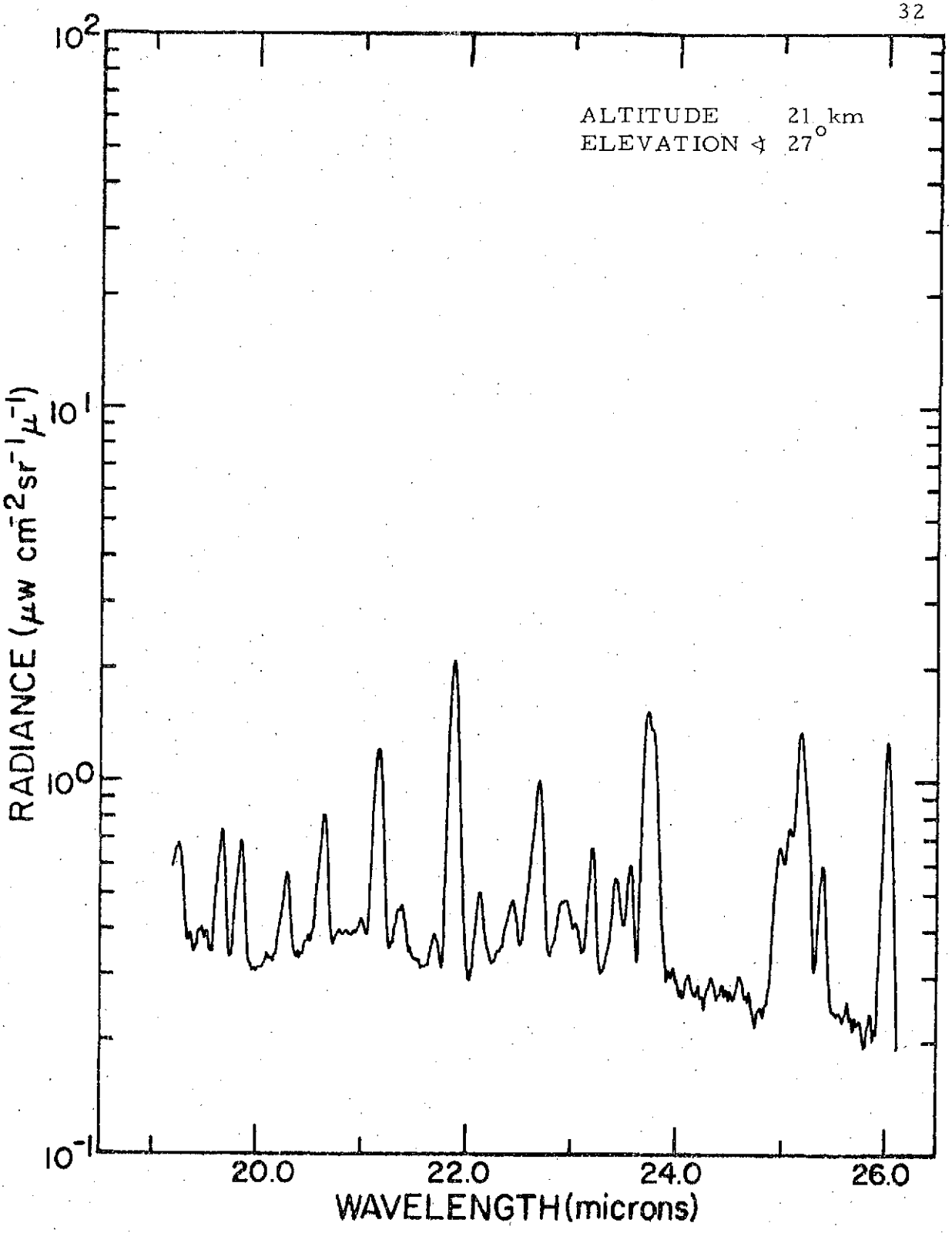

Figure 27. Radiance vs Wavelength for 27 June 1974 flight. Records 112-116 are co-added and time is 0823 MDT.

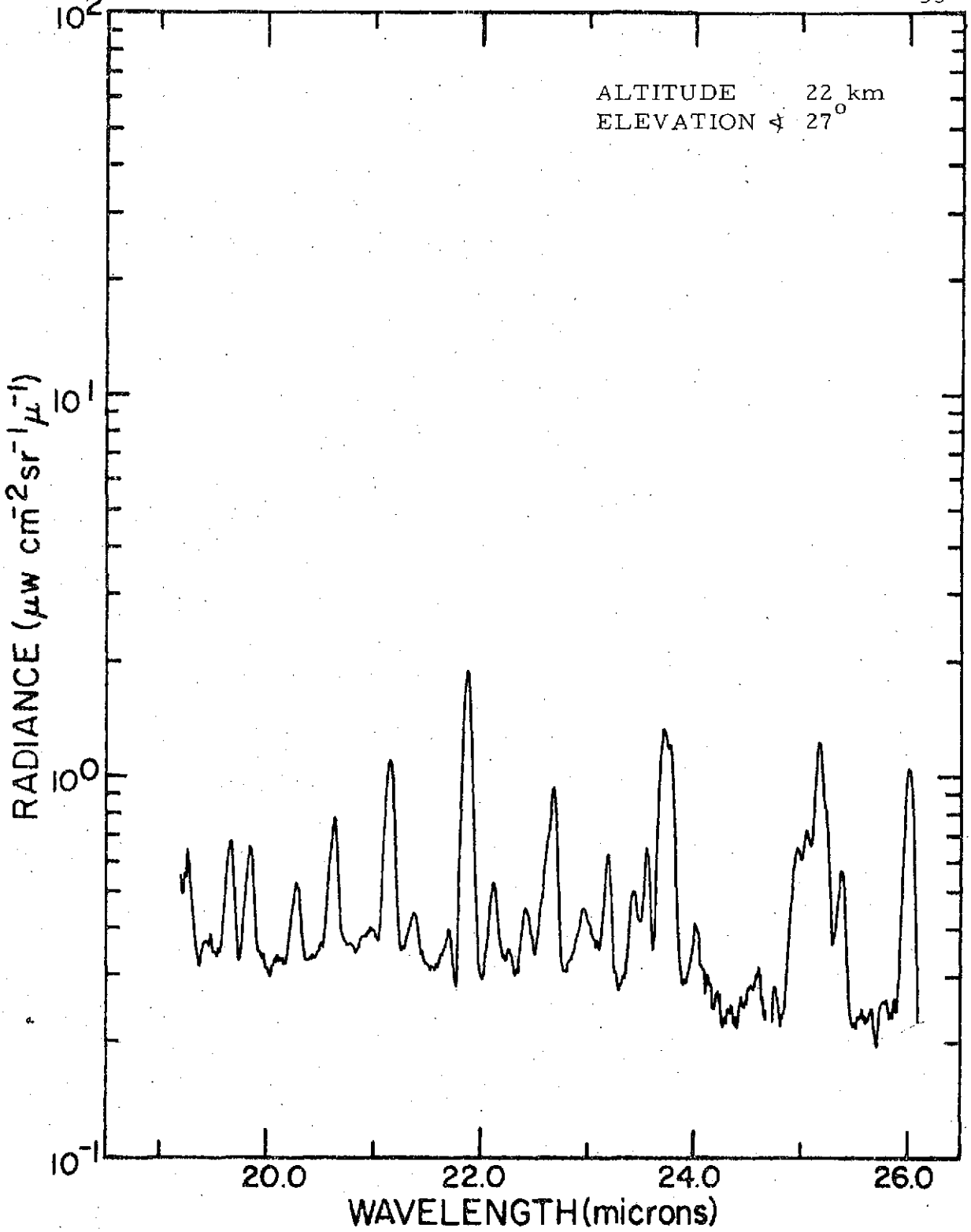

Figure 28. Radiance vs Wavelength for 27 June 1974 flight. Records 118 and 119 are co-added and time is 0827 MDT.

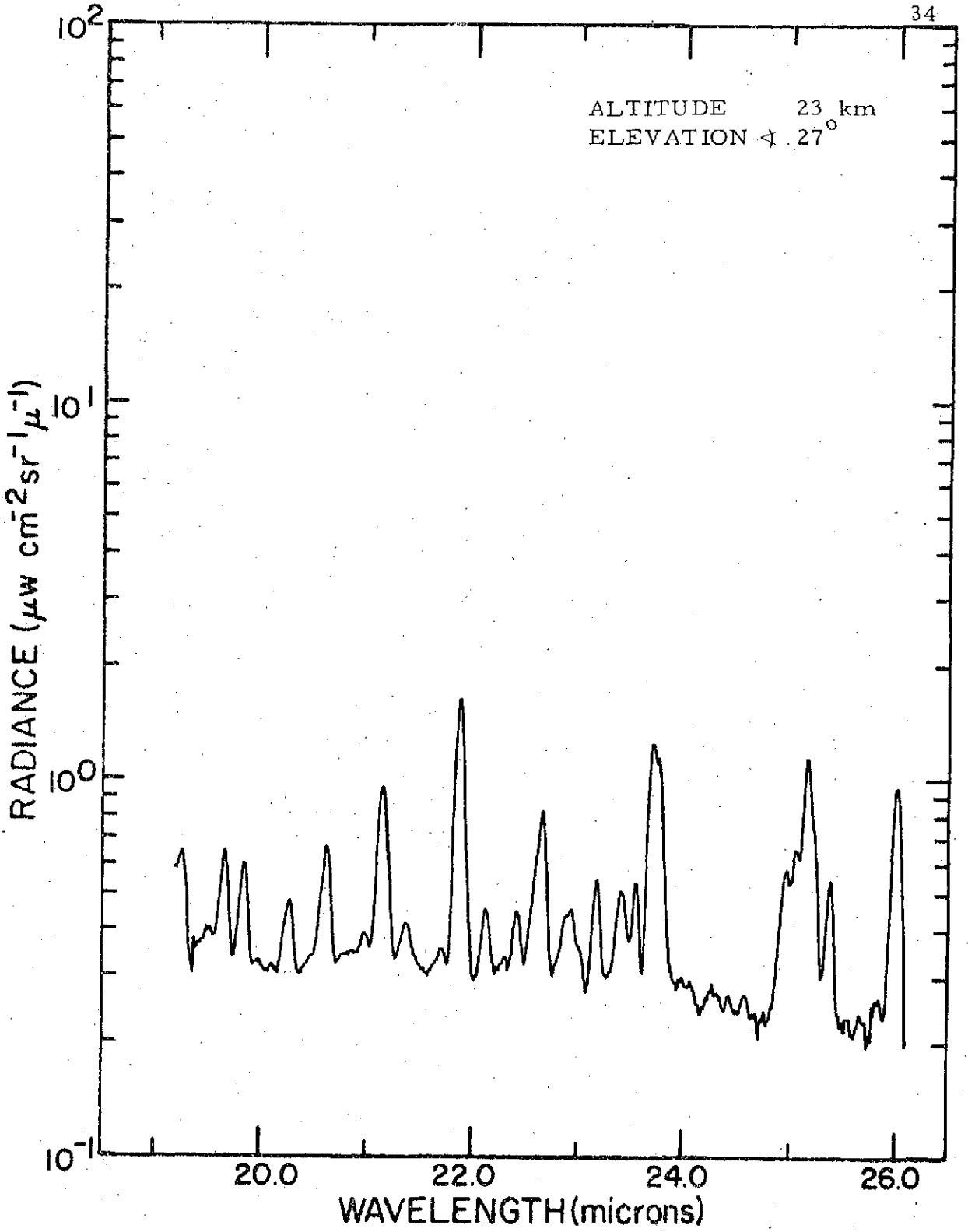

Figure 29. Radiance vs Wavelength for 27 June 1974 flight. Records 123-127 are co-added and time is 0831 MDT.

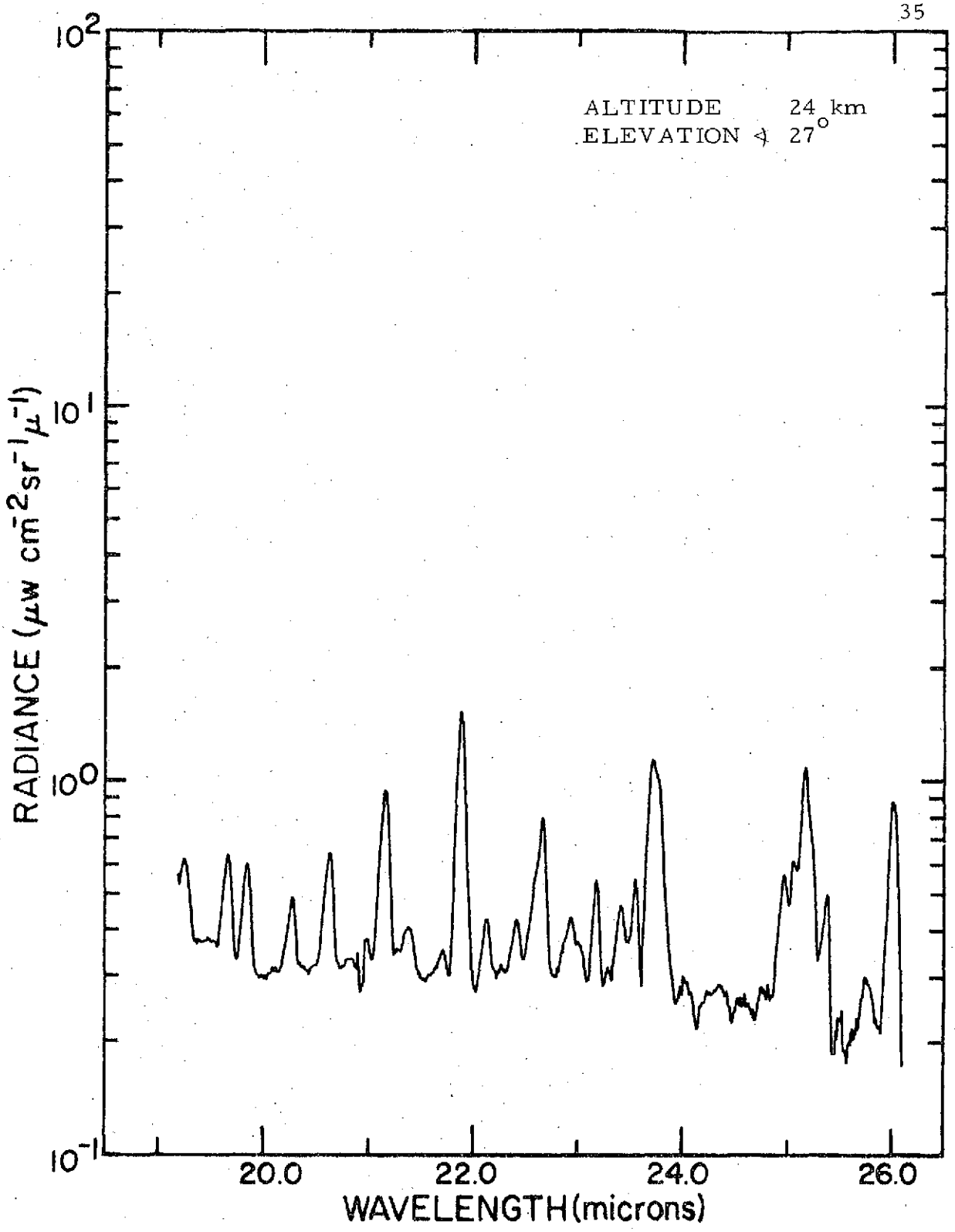

Figure 30. Radiance vs Wavelength for 27 June 1974 flight. Records 128, 130 and 132 are co-added and time is 0836 MDT.

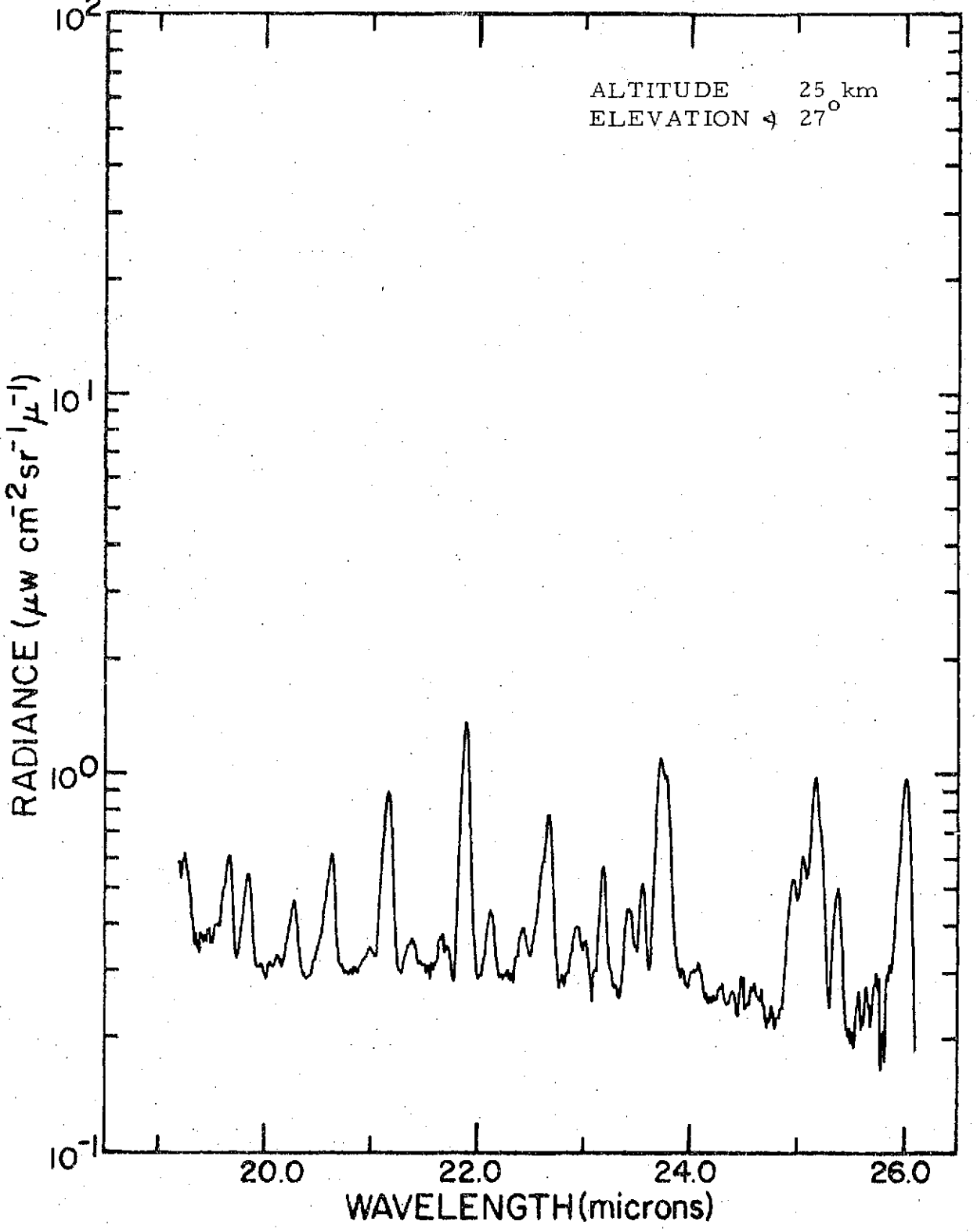

Figure 31. Radiance vs Wavelength for 27 June 1974 flight. Records 134 and 135 are co-added and time is 0839 MDT.

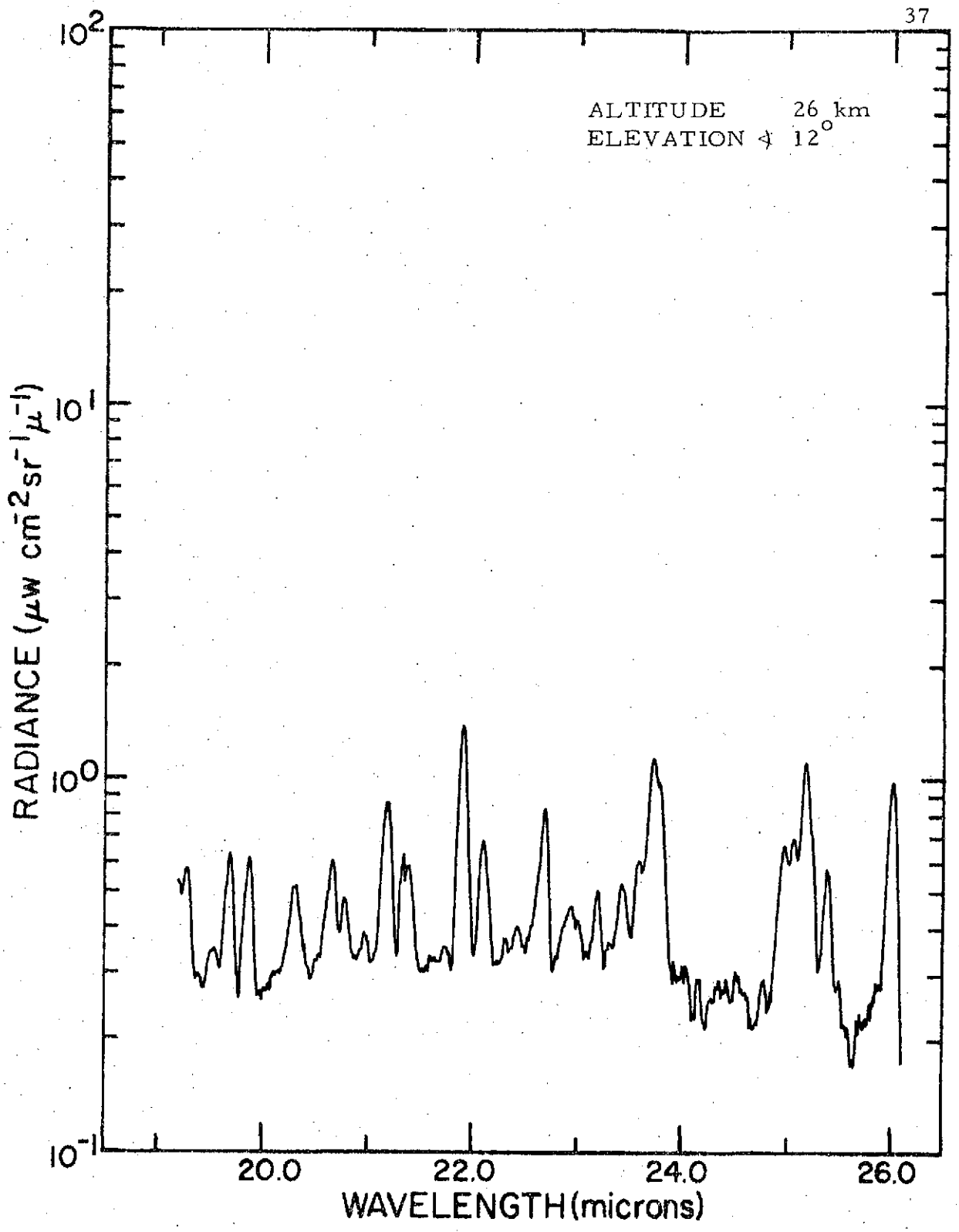

Figure 32. Radiance vs Wavelength for 27 June 1974 flight. Records 137, 138, 141 and 142 are co-added and time is 0842 MDT.

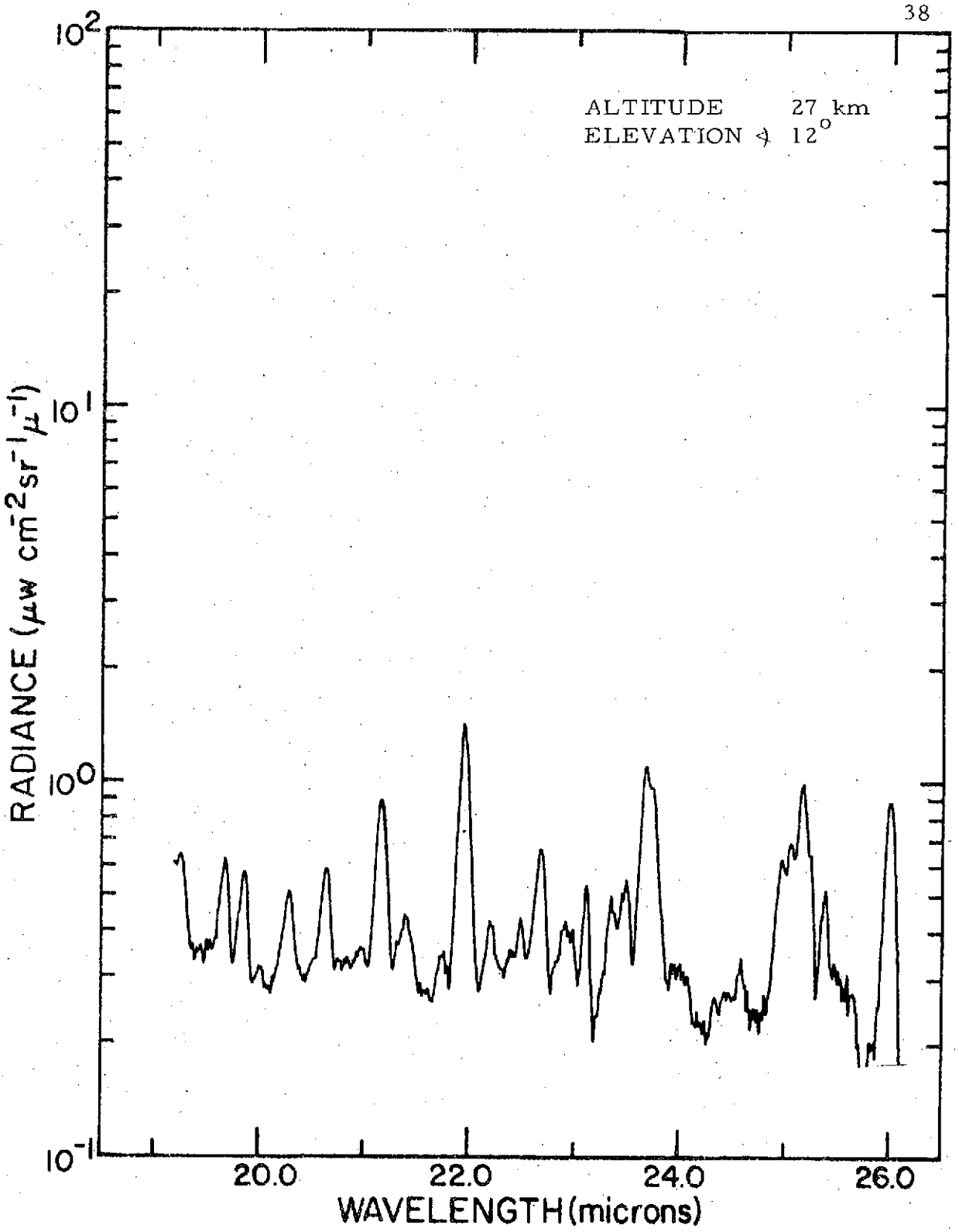

Figure 33. Radiance vs Wavelength for 27 June 1974 flight. Records 144-147 are co-added and time is 0847 MDT.

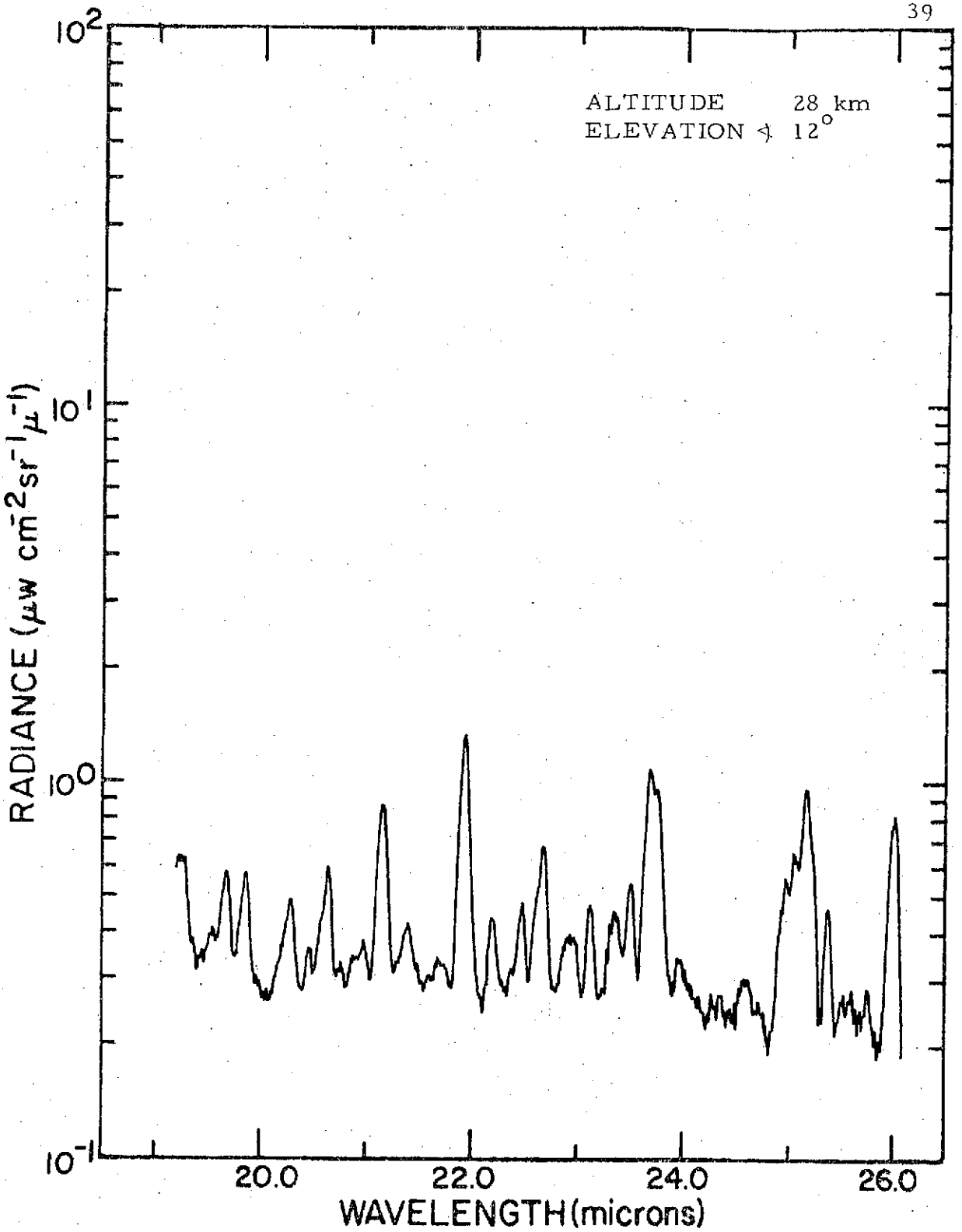

Figure 34. Radiance vs Wavelength for 27 June 1974 flight. Records 148-152 are co-added and time is 0850 MDT.

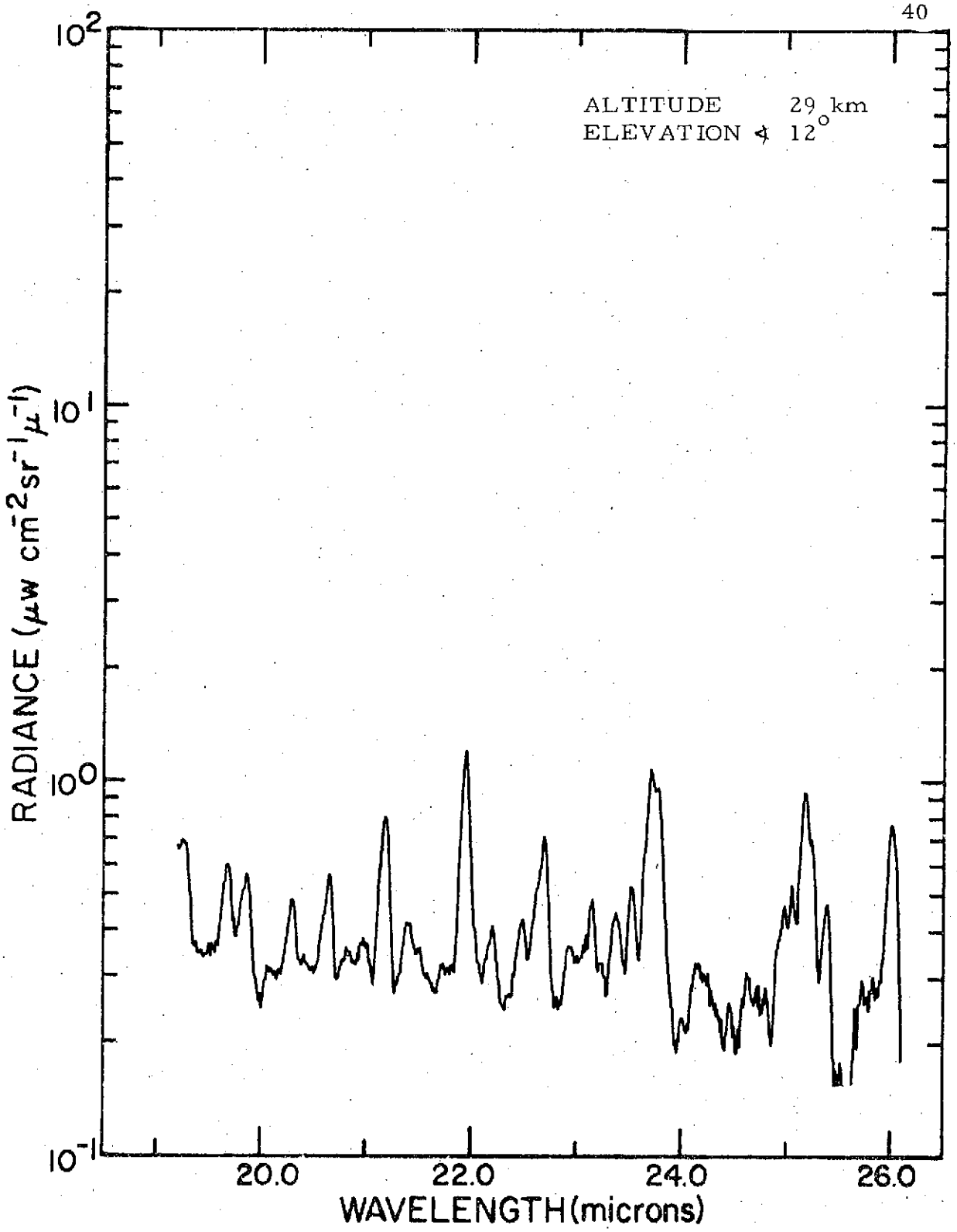

Figure 35. Radiance vs Wavelength for 27 June 1974 flight. Records 153-156 are co-added and time is 0853 MDT.

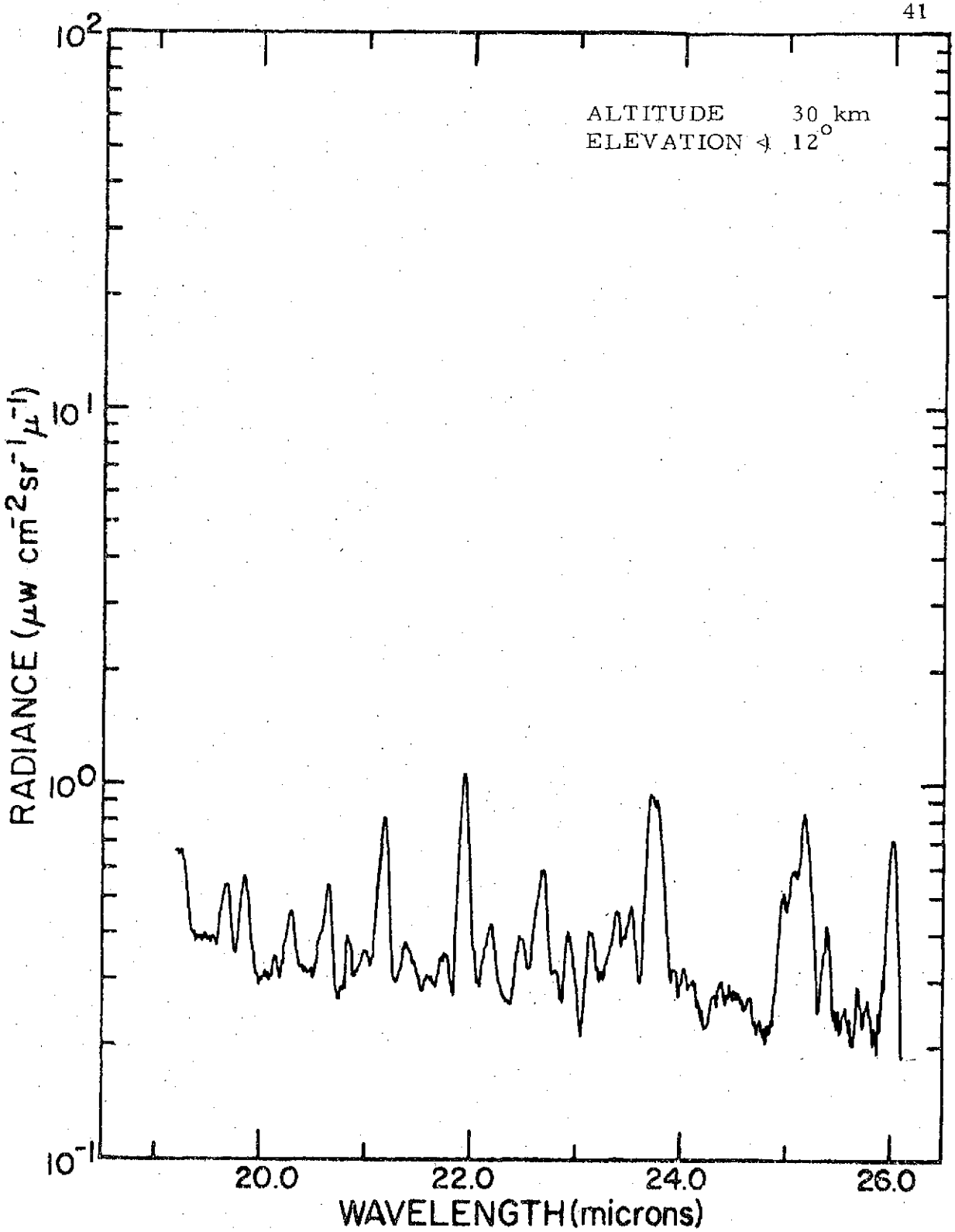

Figure 36. Radiance vs Wavelength for 27 June 1974 flight. Records 157-160 are co-added and time is 0856 MDT.

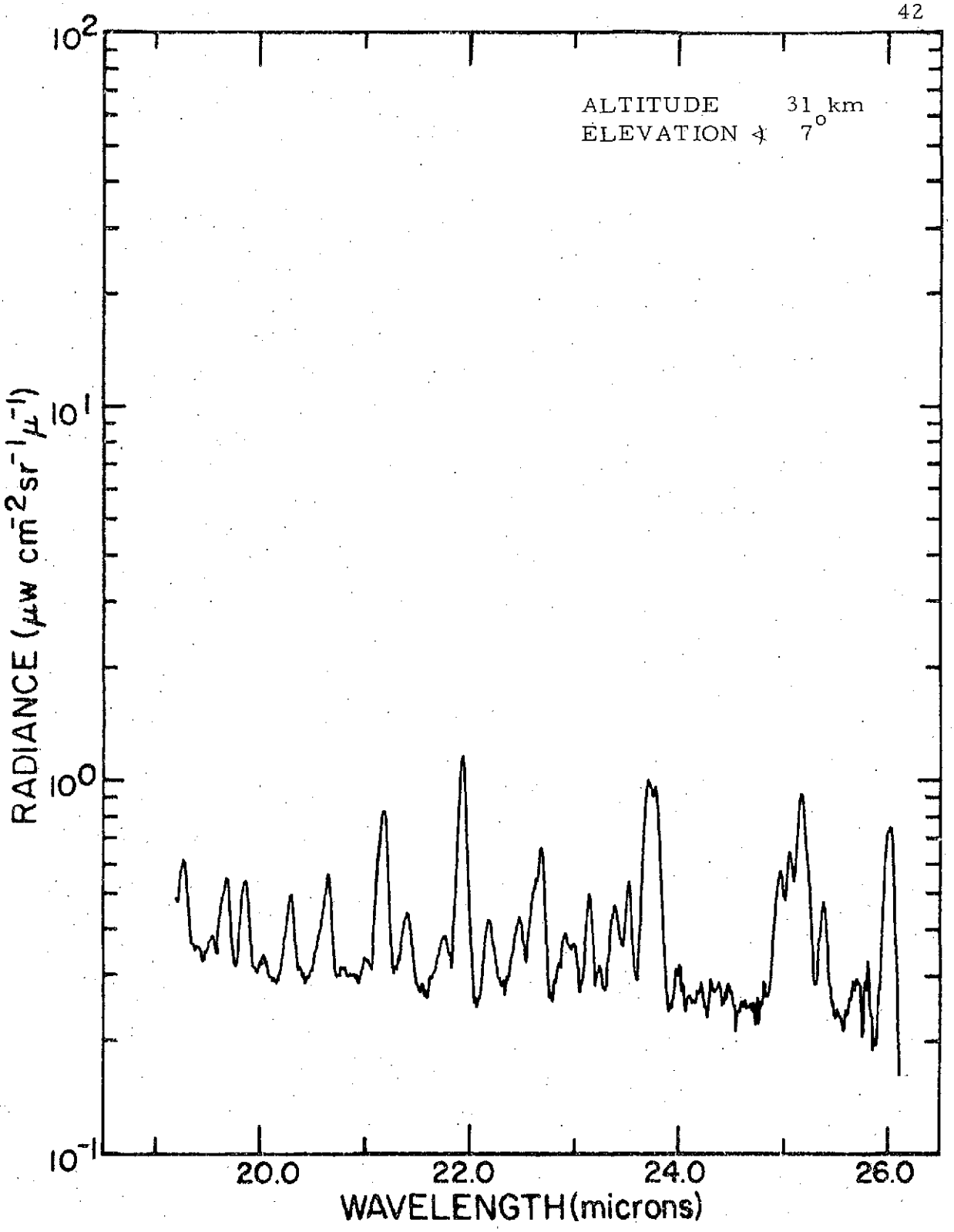

Figure 37. Radiance vs Wavelength for 27 June 1974 flight. Records 163-165, 167 and 168 are co-added and time is 0901 MDT.

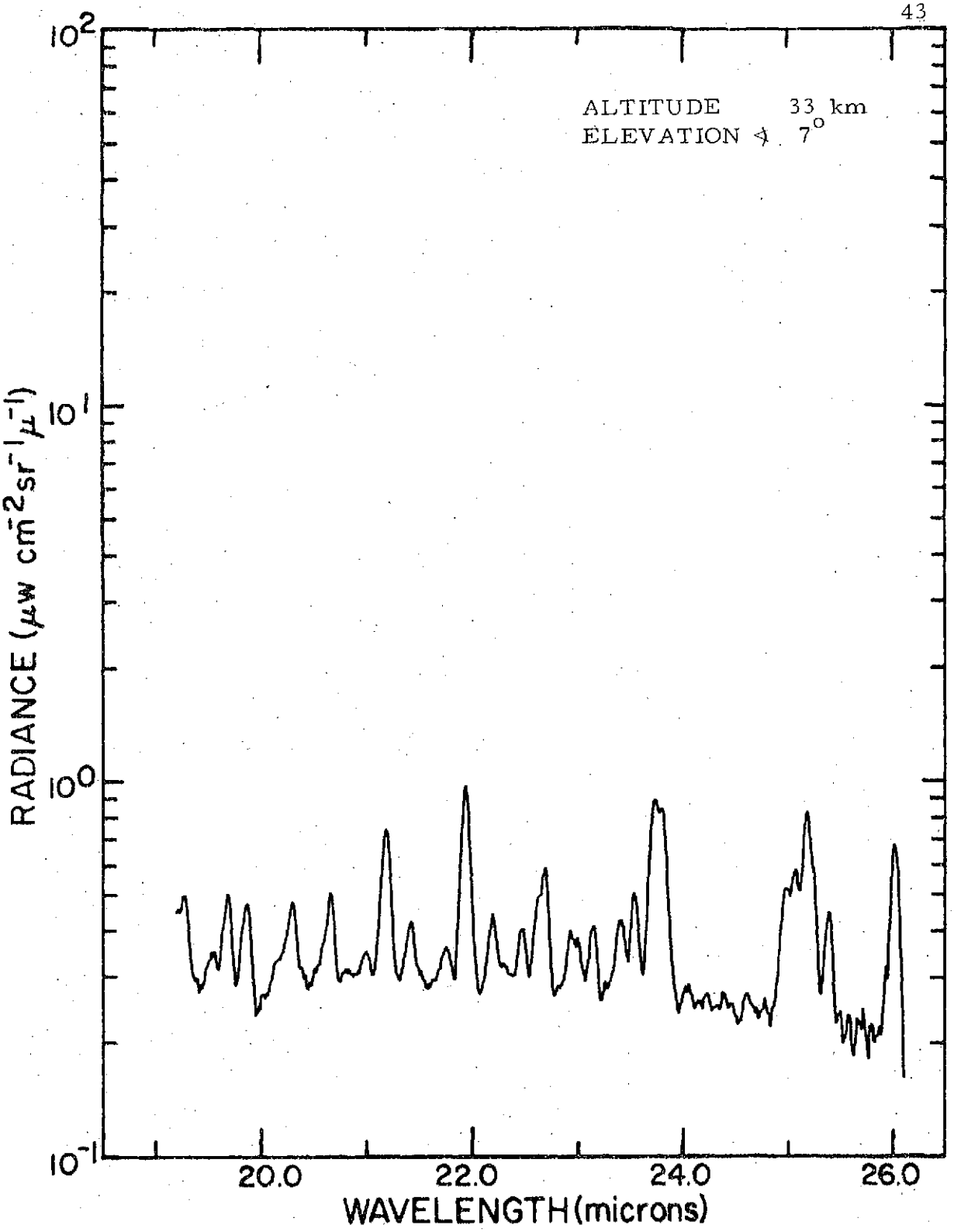

Figure 38. Radiance vs Wavelength for 27 June 1974 flight. Records 169-180 are co-added and time is 0907 MDT.

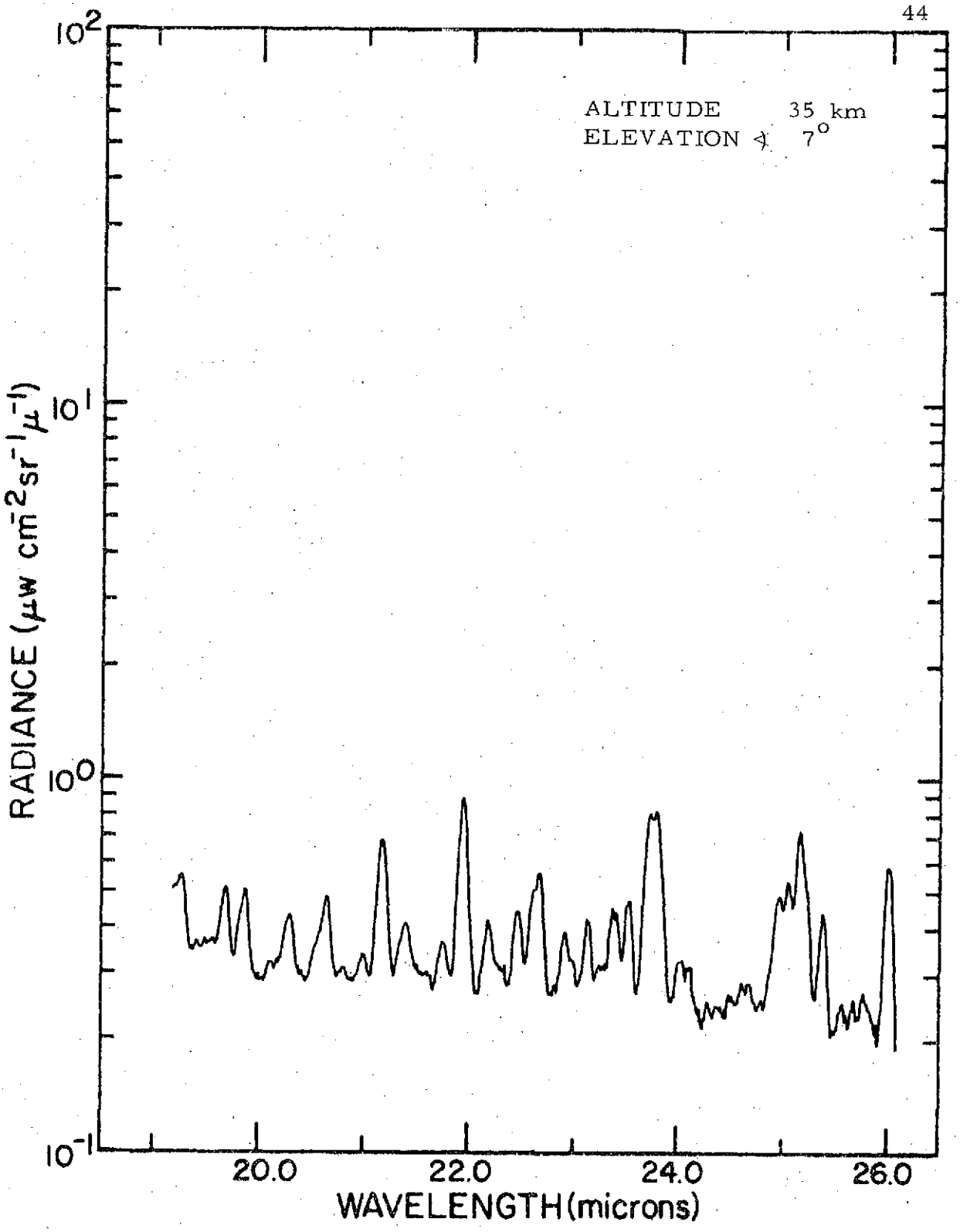

Figure 39. Radiance vs Wavelength for 27 June 1974 flight. Records 181, 183, 184, 186-191 are co-added and time is 0915 MDT.

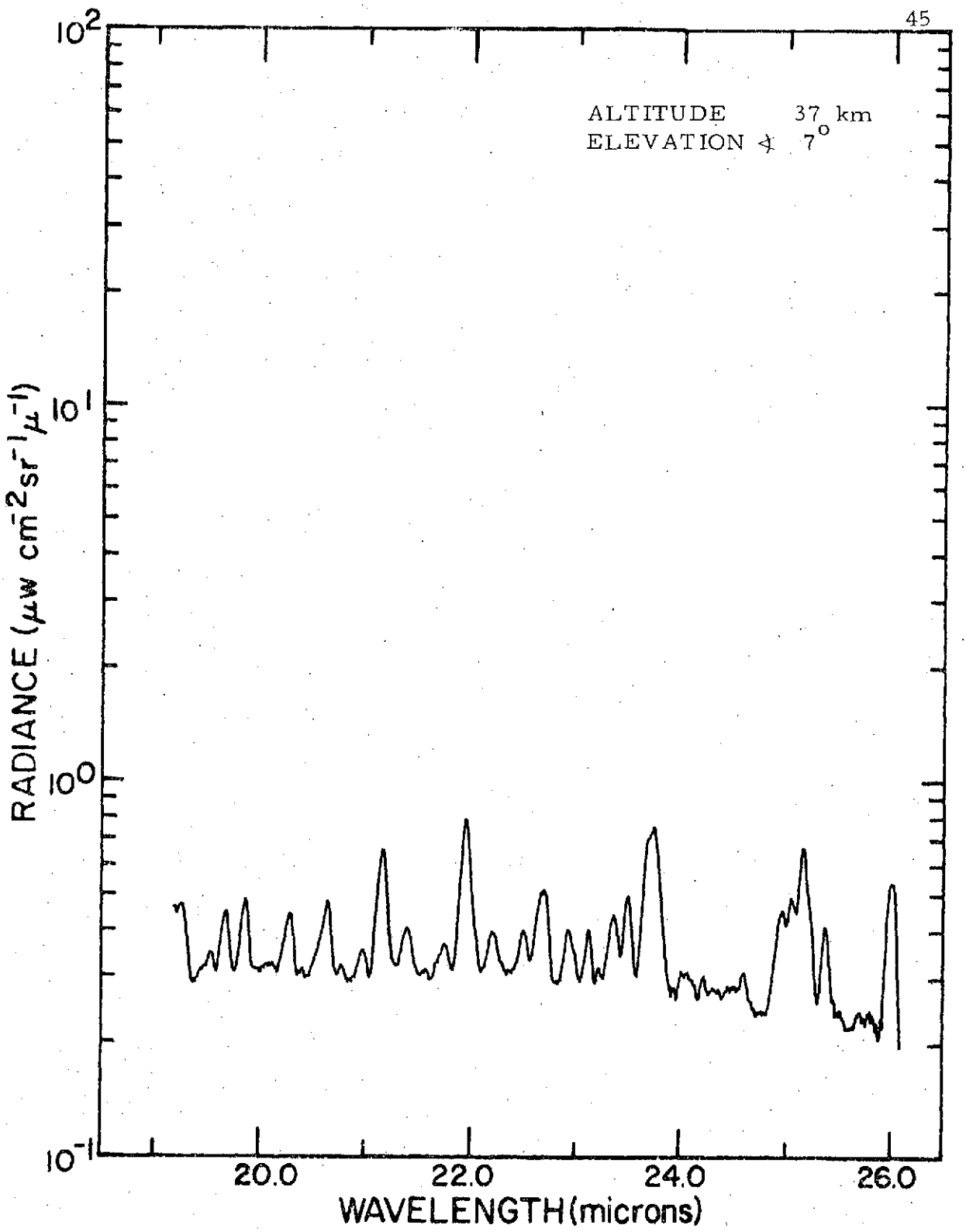

Figure 40. Radiance vs Wavelength for 27 June 1974 flight. Records 192-204 are co-added and time is 0924 MDT.

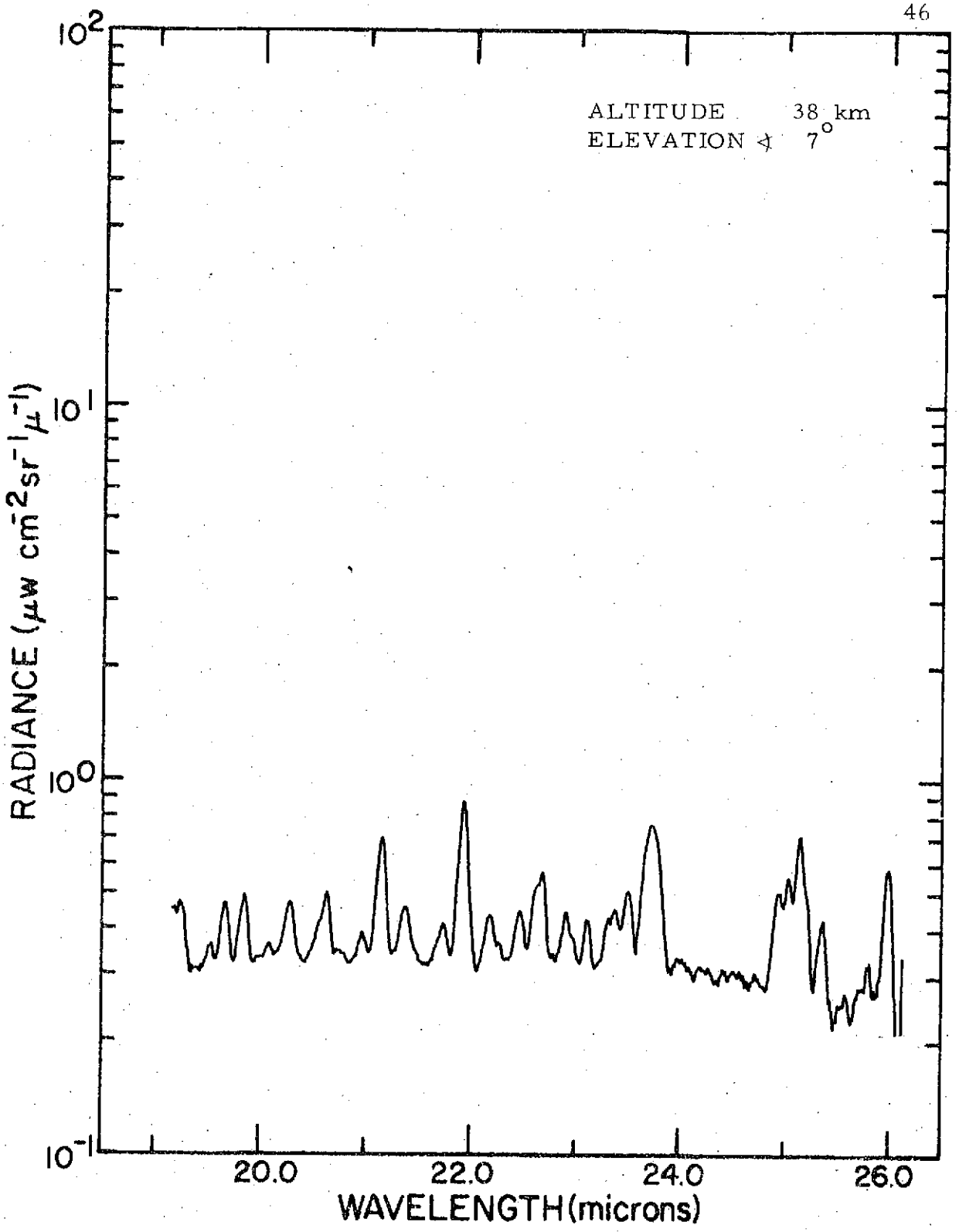

Figure 41. Radiance vs Wavelength for 27 June 1974 flight. Records 205-212 and 219-226 are co-added and time is 0936 MDT.

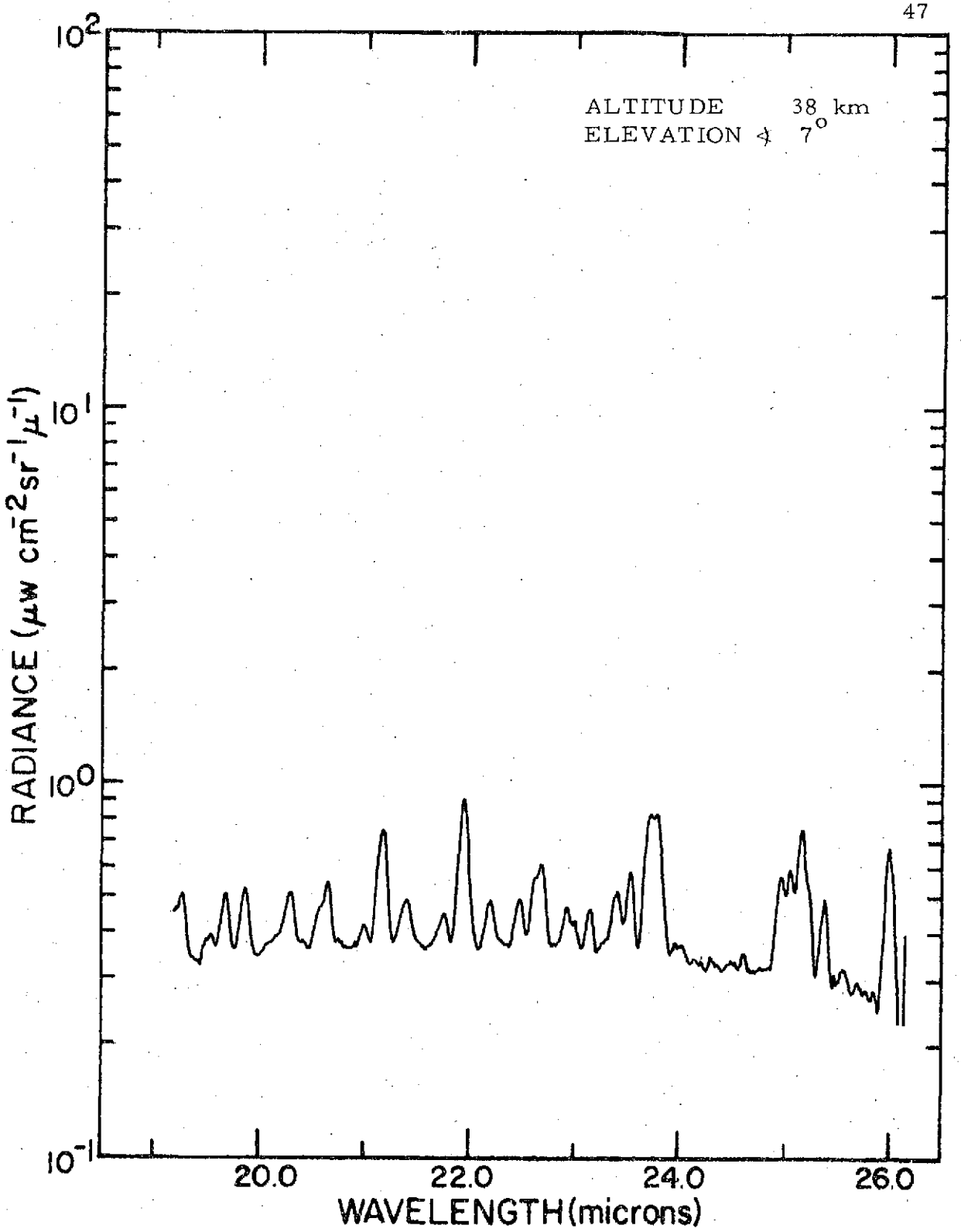

Figure 42. Radiance vs Wavelength for 27 June 1974 flight. Records 227-247 are co-added and time is 0951 MDT.

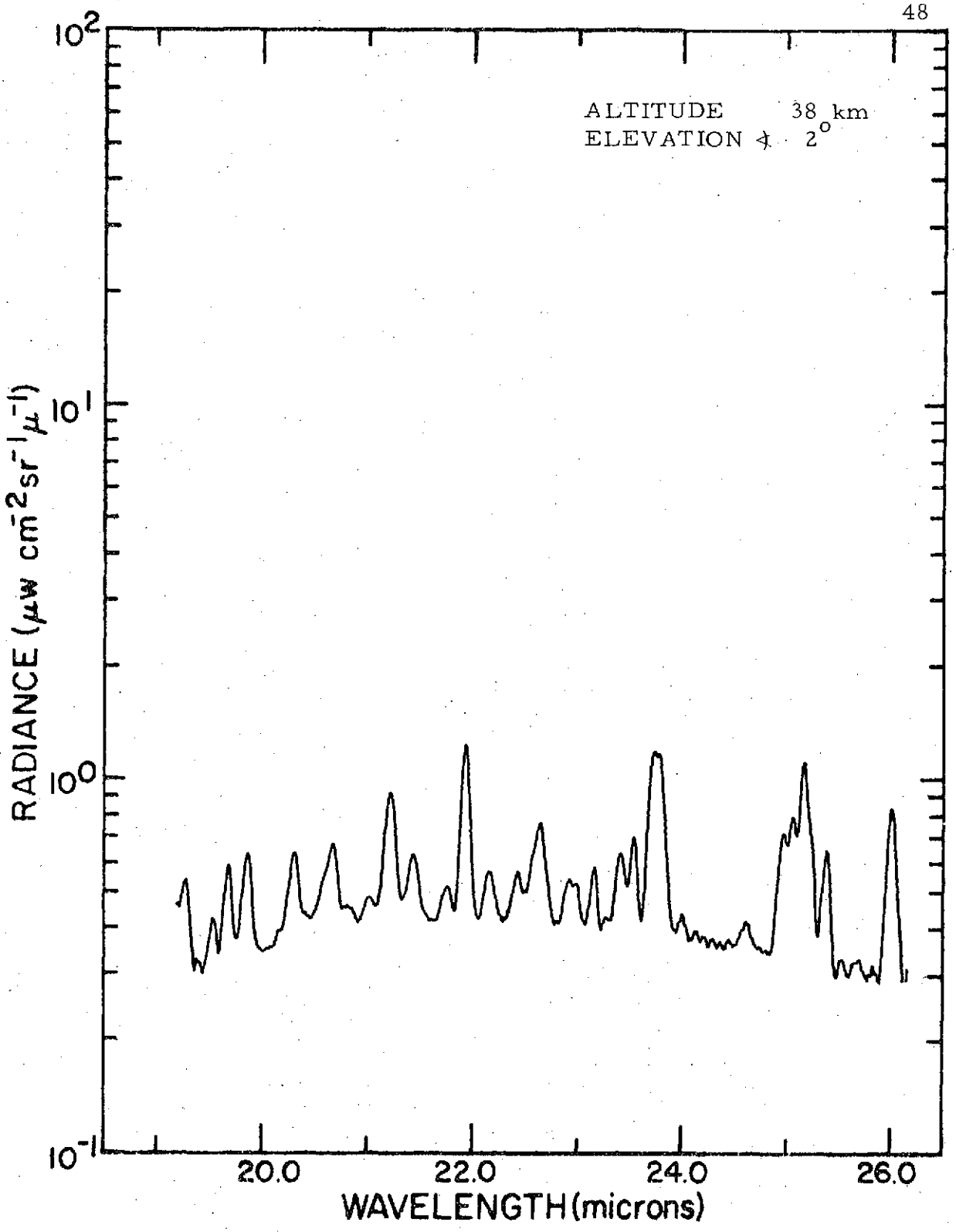

Figure 43. Radiance vs Wavelength for 27 June 1974 flight. Records 250-259 and 261-275 are co-added and time is 1010 MDT.

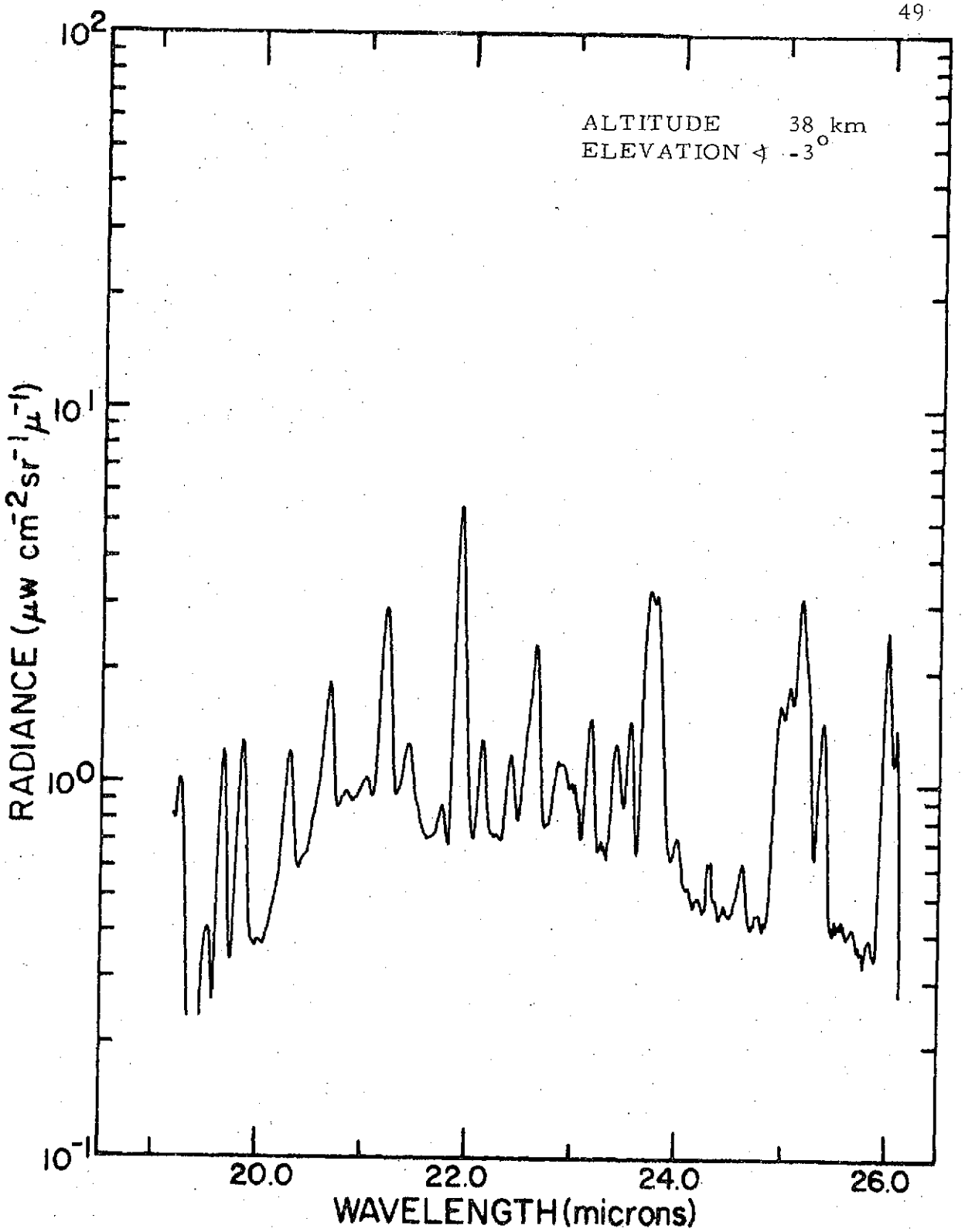

Figure 44. Radiance vs Wavelength for 27 June 1974 flight. Records 278-280 are co-added and time is 1021 MDT.

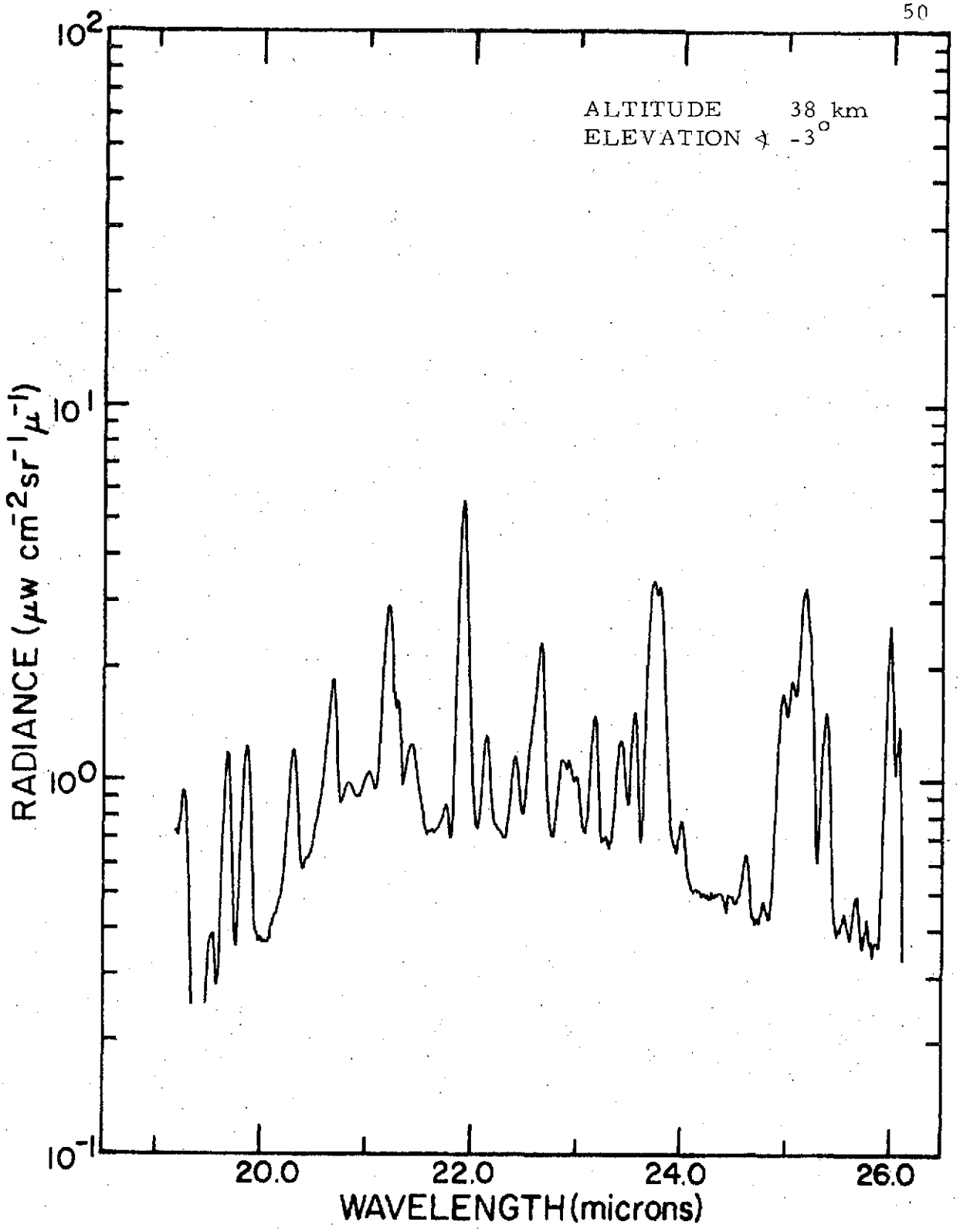

Figure 45. Radiance vs Wavelength for 27 June 1974 flight. Records 281-283 are co-added and time is 1023 MDT.

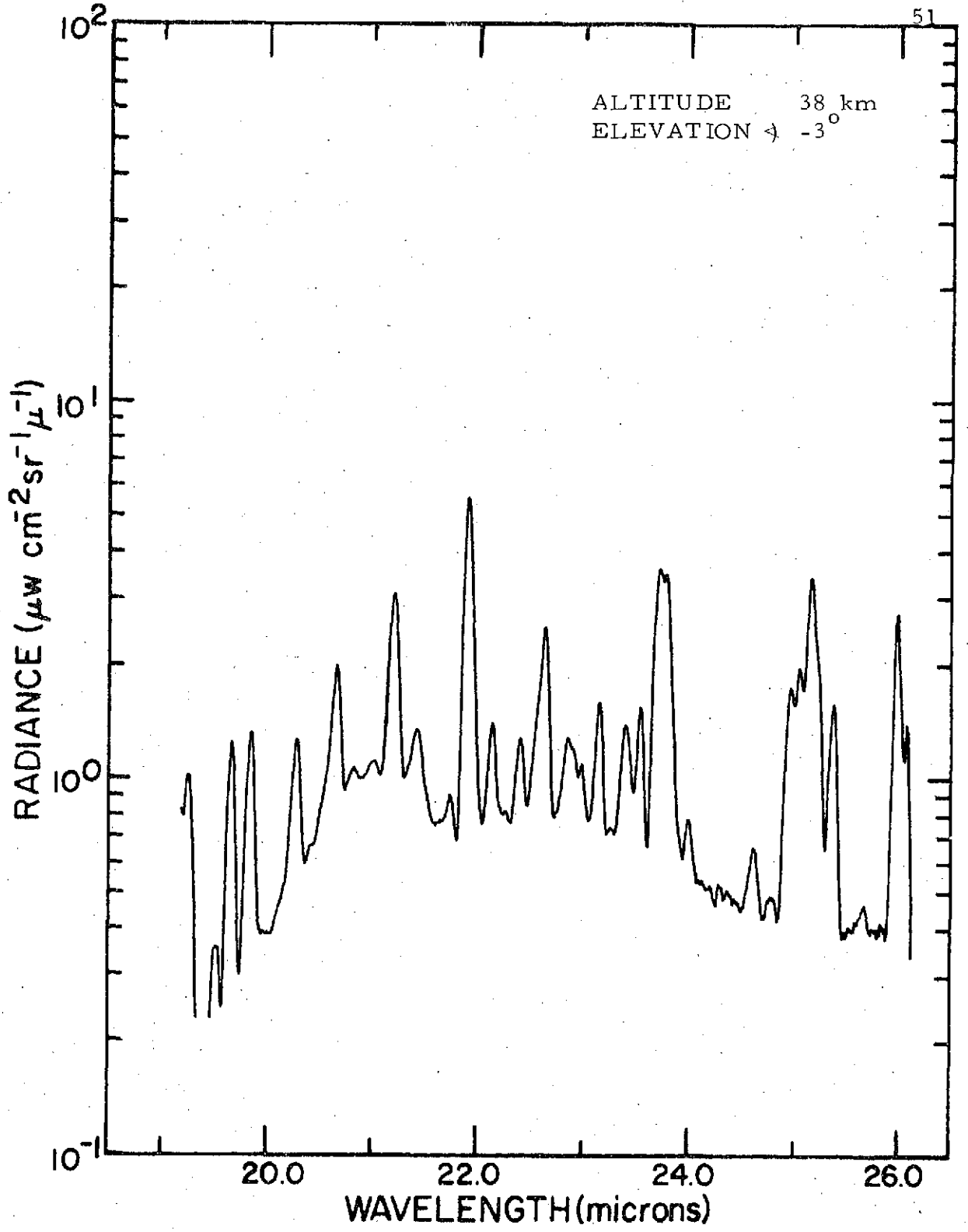

Figure 46. Radiance vs Wavelength for 27 June 1974 flight. Records 284-286 are co-added and time is 1025 MDT.

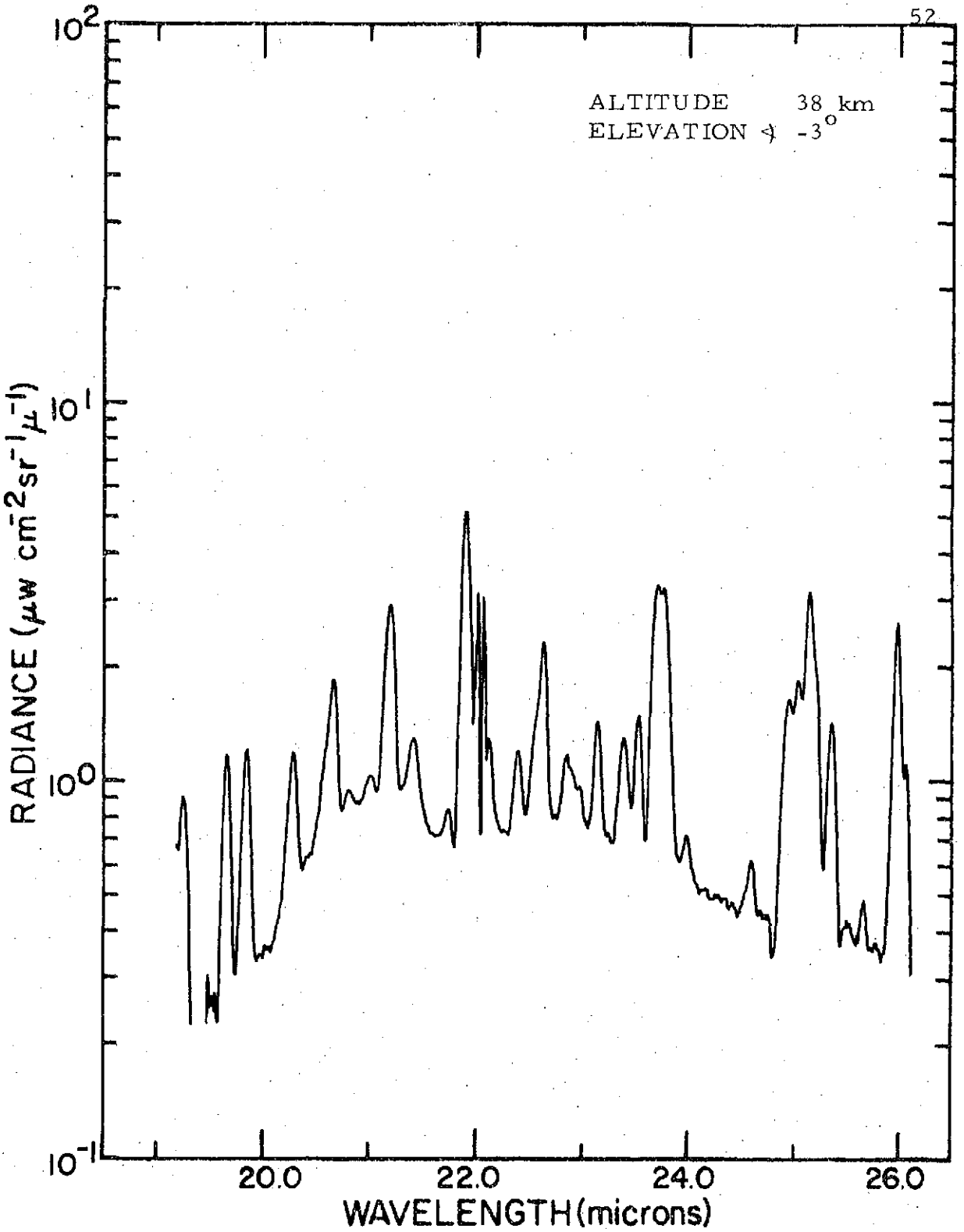

Figure 47. Radiance vs Wavelength for 27 June 1974 flight. Records 287-289 are co-added and time is 1027 MDT.

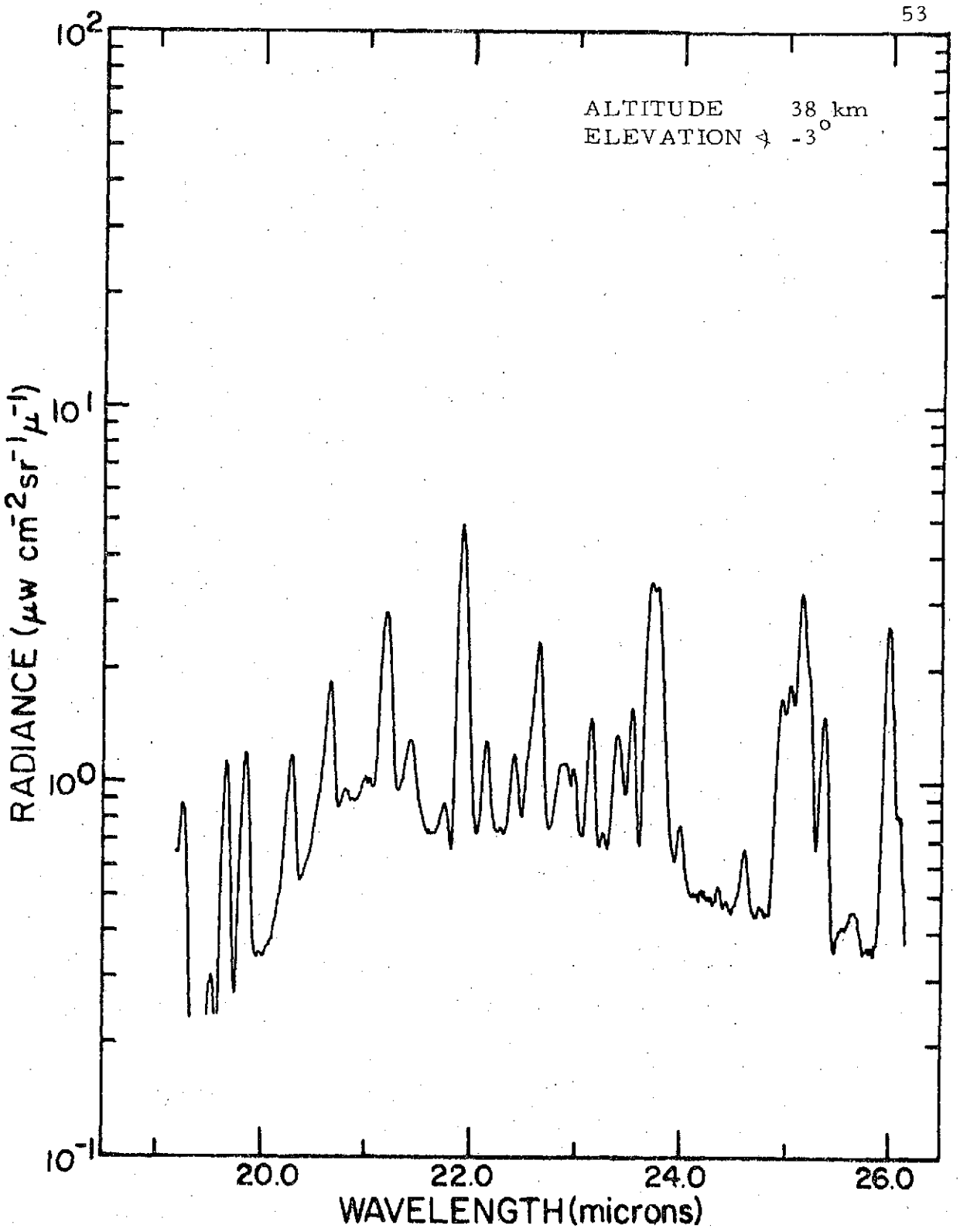

Figure 48. Radiance vs Wavelength for 27 June 1974 flight. Records 290-292 are co-added and time is 1030 MDT.

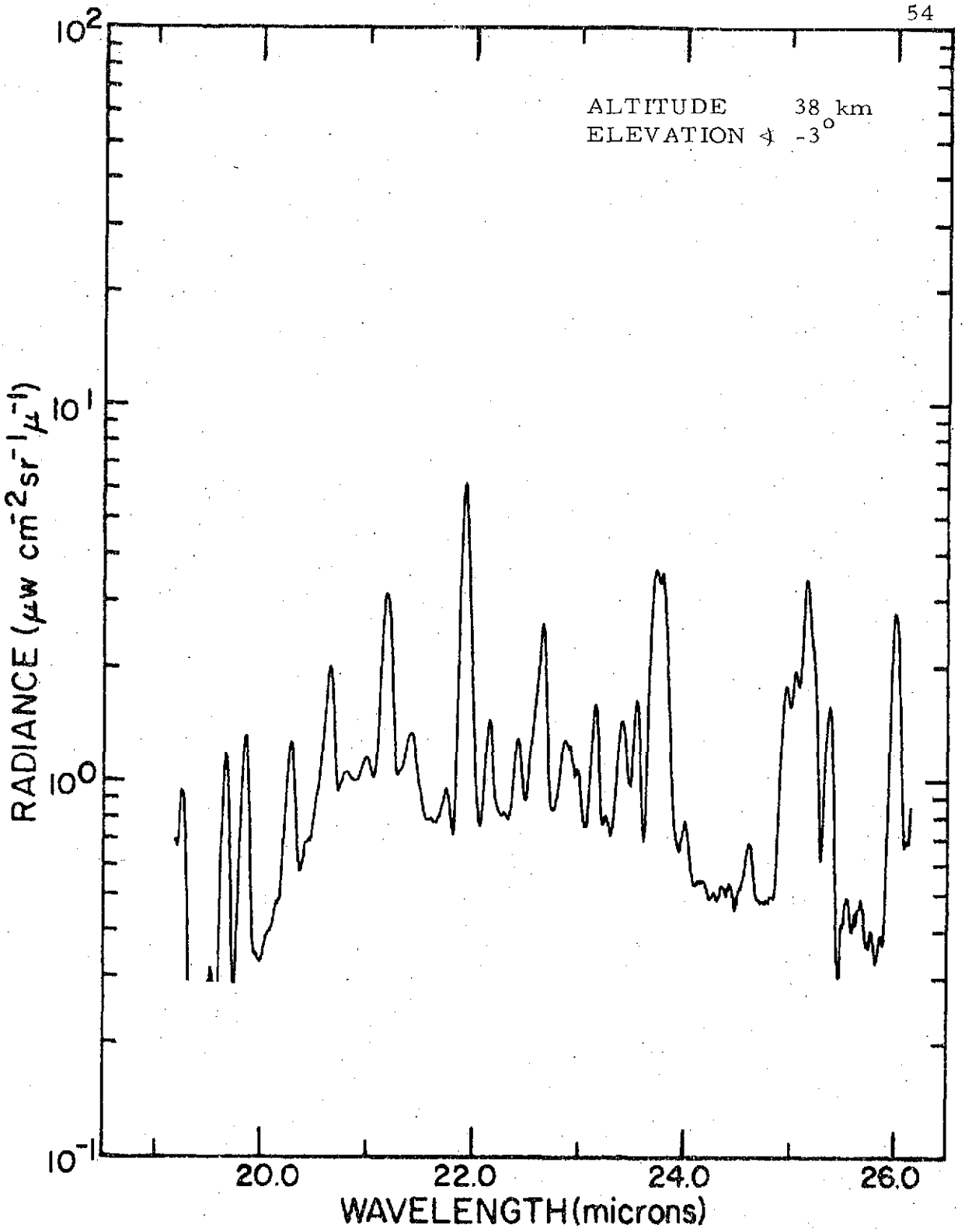

Figure 49. Radiance vs Wavelength for 27 June 1974 flight. Records 293-295 are co-added and time is 1032 MDT.

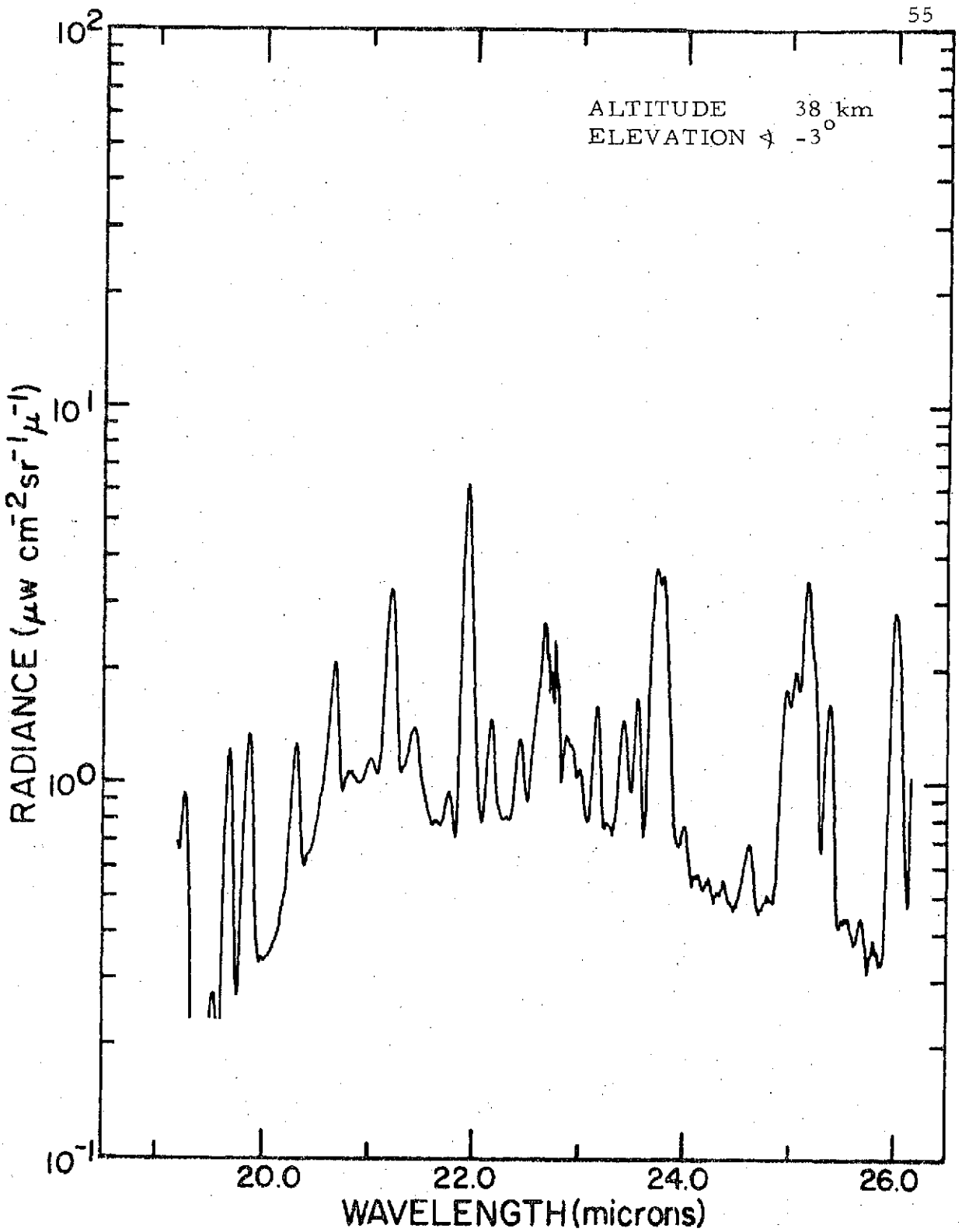

Figure 50. Radiance vs Wavelength for 27 June 1974 flight. Records 296-298 are co-added and time is 1034 MDT.

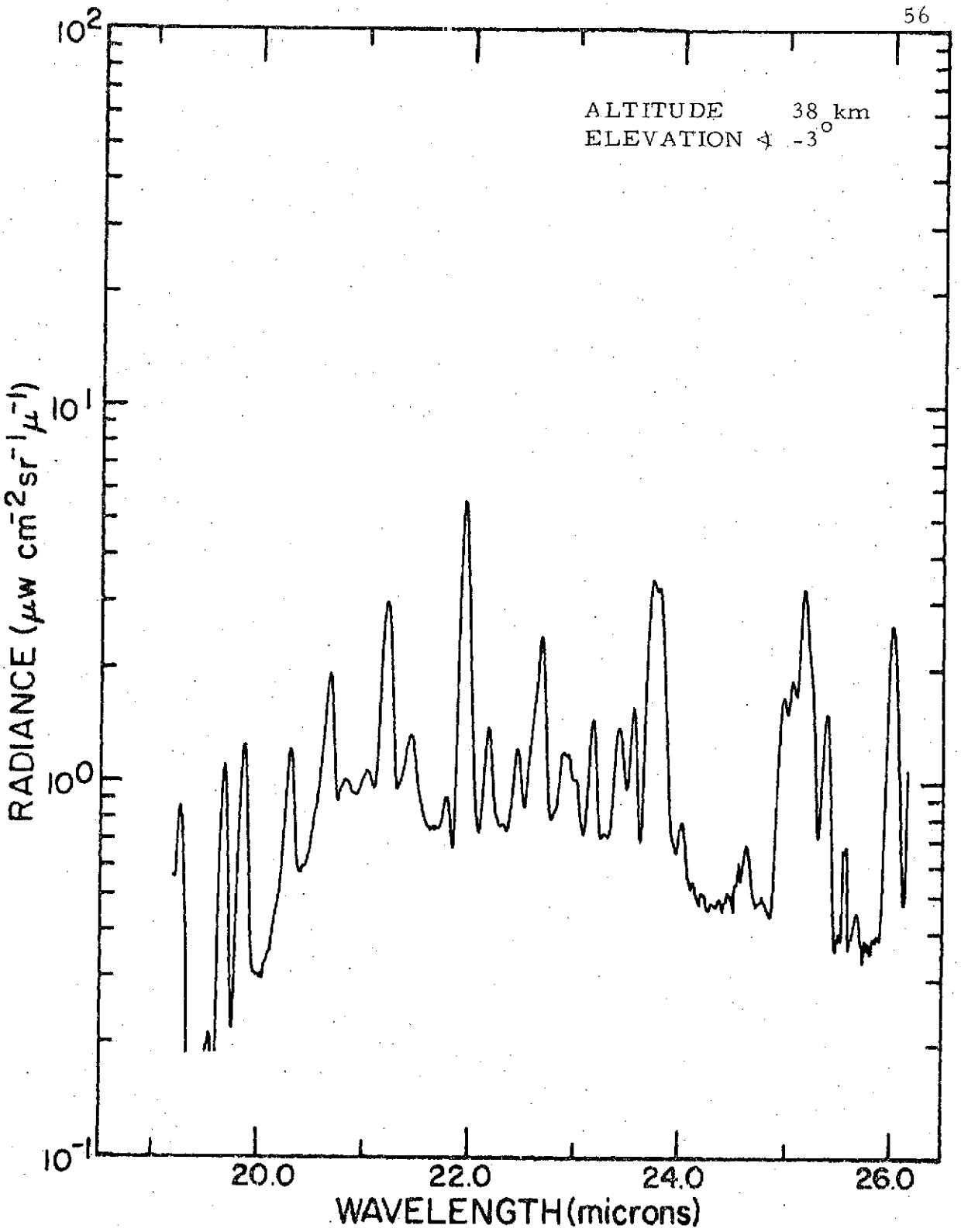

Figure 51. Radiance vs Wavelength for 27 June 1974 flight. Records 299-301 are co-added and time is 1036 MDT.

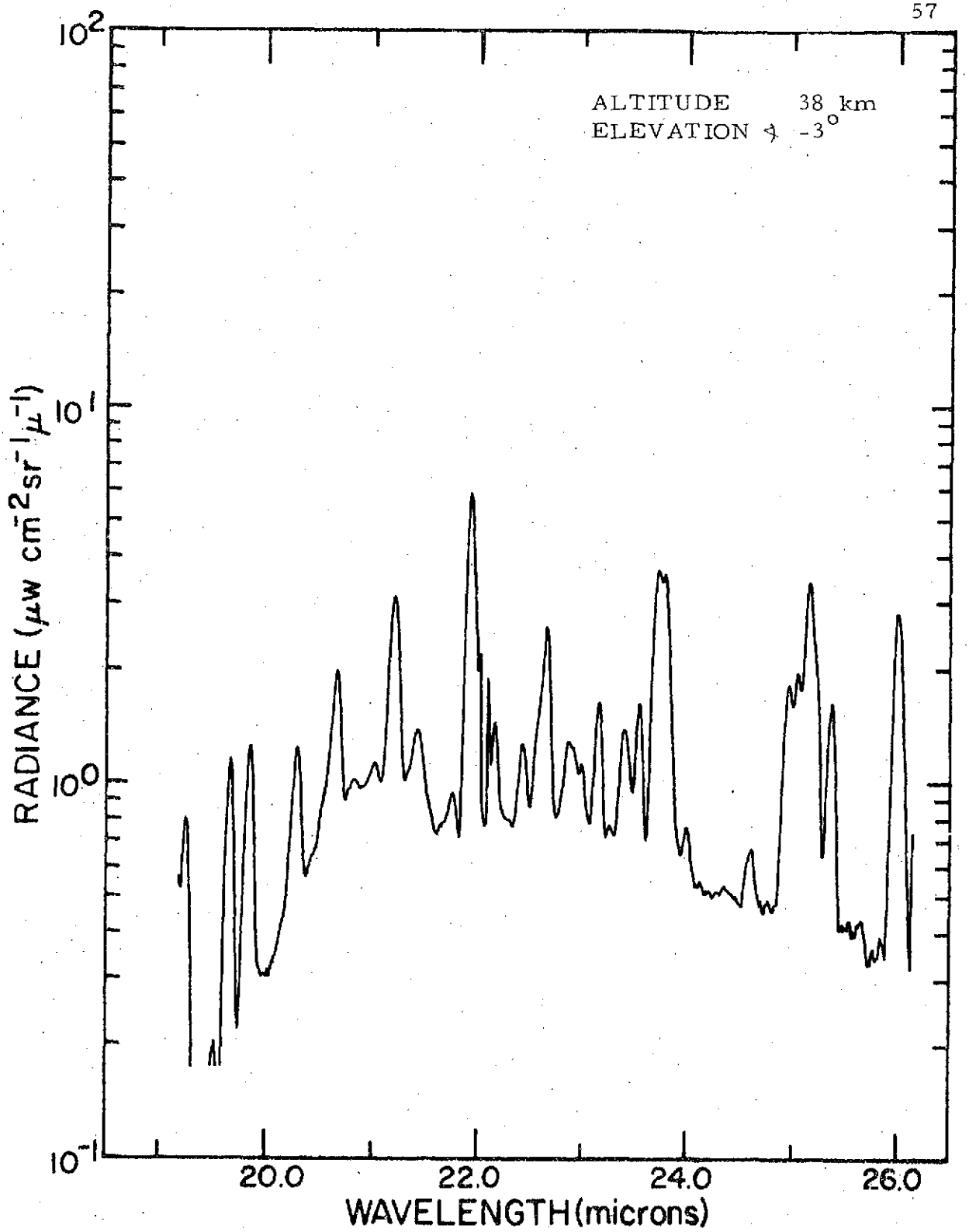

Figure 52. Radiance vs Wavelength for 27 June 1974 flight. Records 302-304 are co-added and time is 1038 MDT.

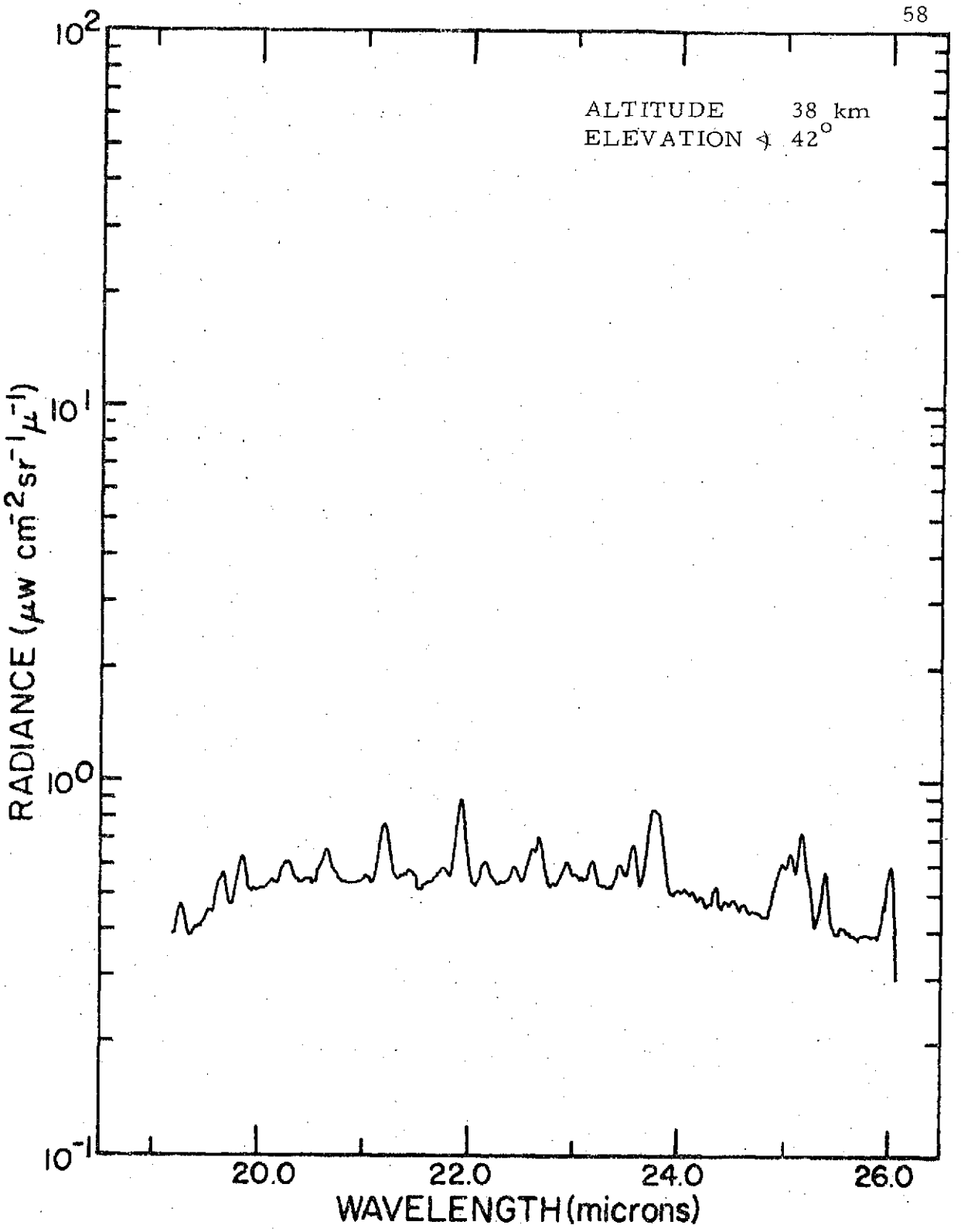

Figure 53. Radiance vs Wavelength for 27 June 1974 flight. Records 308-309 and 311-318 are co-added and time is 1045 MDT.

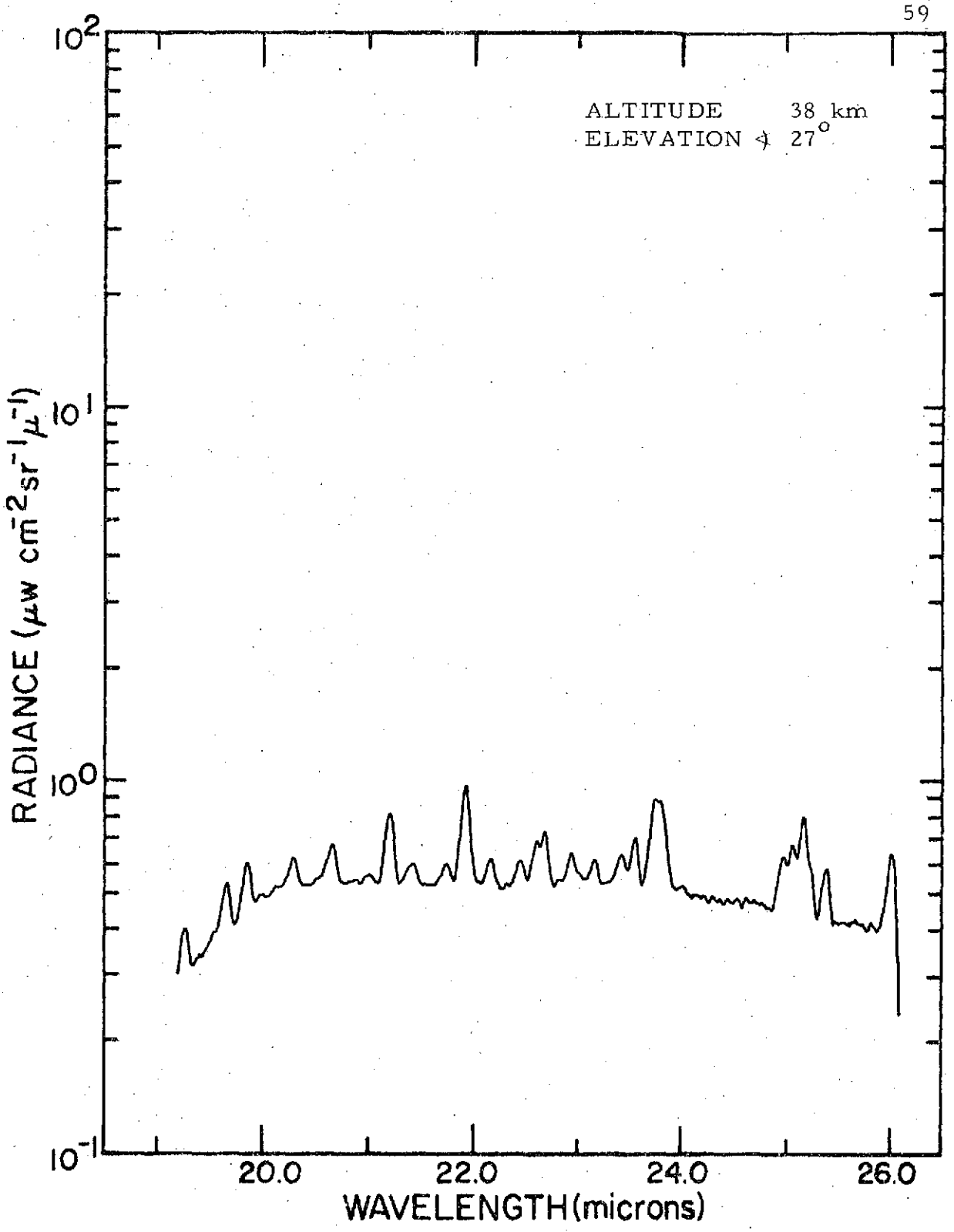

Figure 54. Radiance vs Wavelength for 27 June 1974 flight. Records 322, 323, 325, 326, 328-330, 333-338, 340-342, 345 and 346 are co-added and time is 1104 MDT.

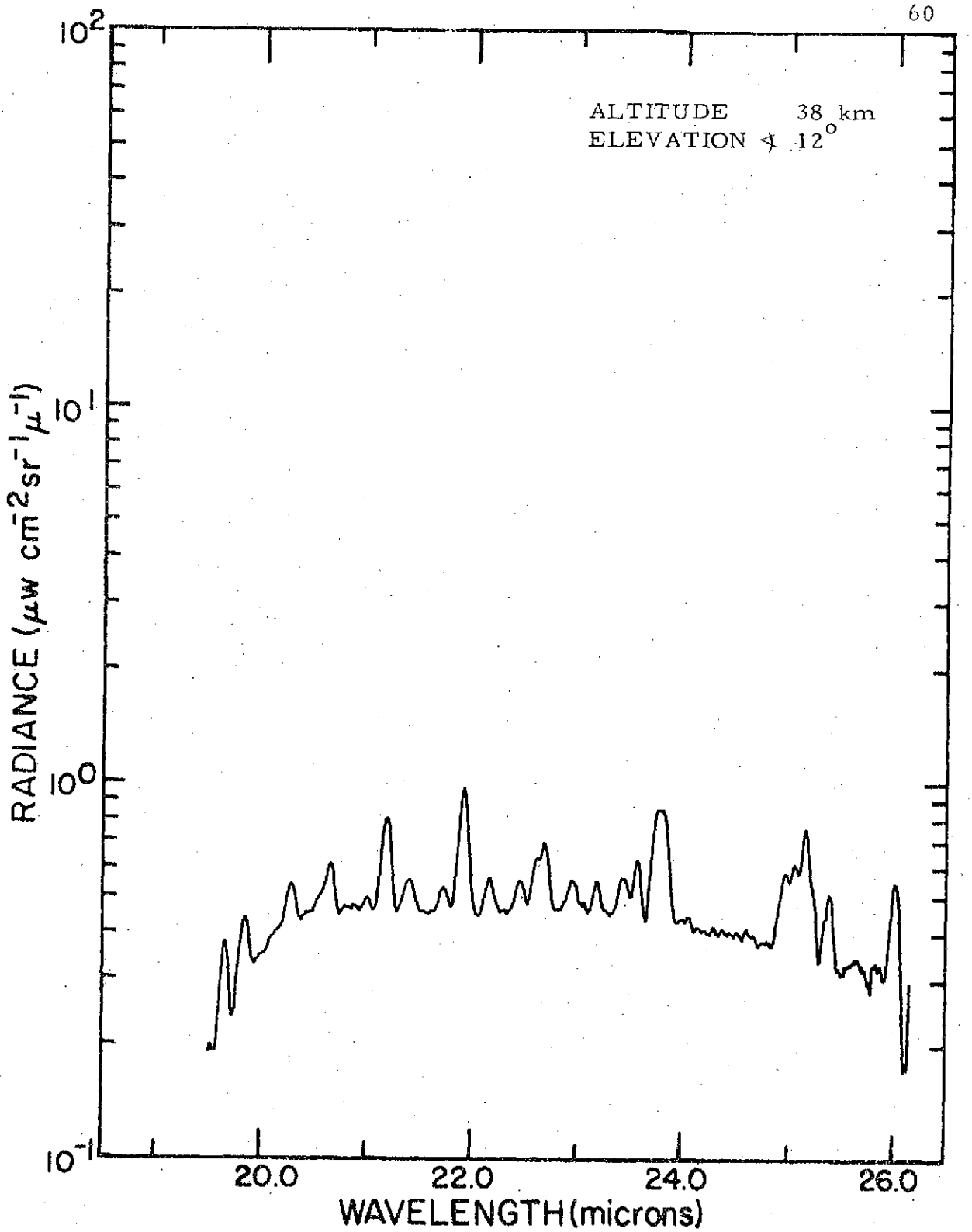

Figure 55. Radiance vs Wavelength for 27 June 1974 flight. Records 349-361 are co-added and time is 1115 MDT.

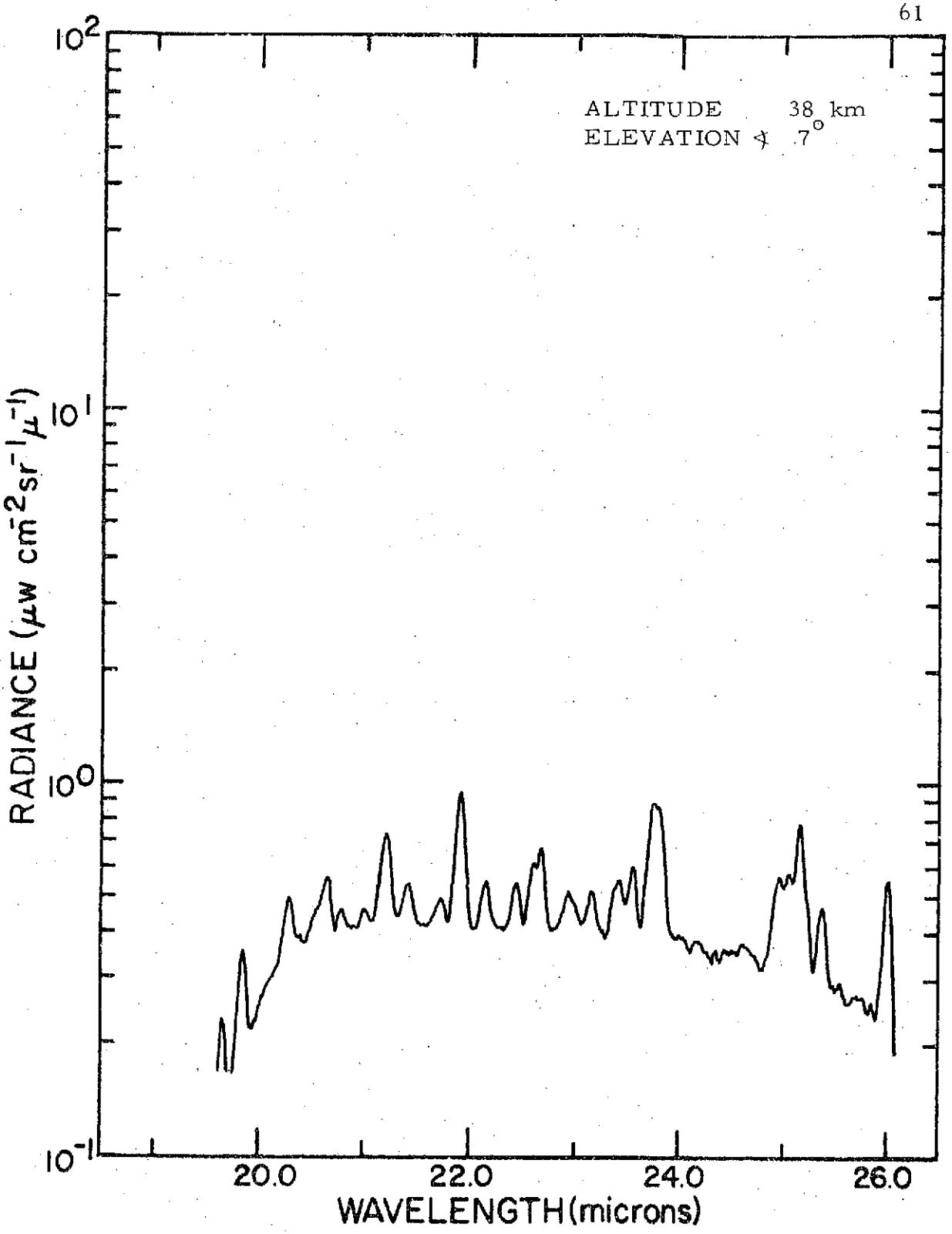

Figure 56. Radiance vs Wavelength for 27 June 1974 flight. Records 363 and 365-375 are co-added and time is 1125 MDT.

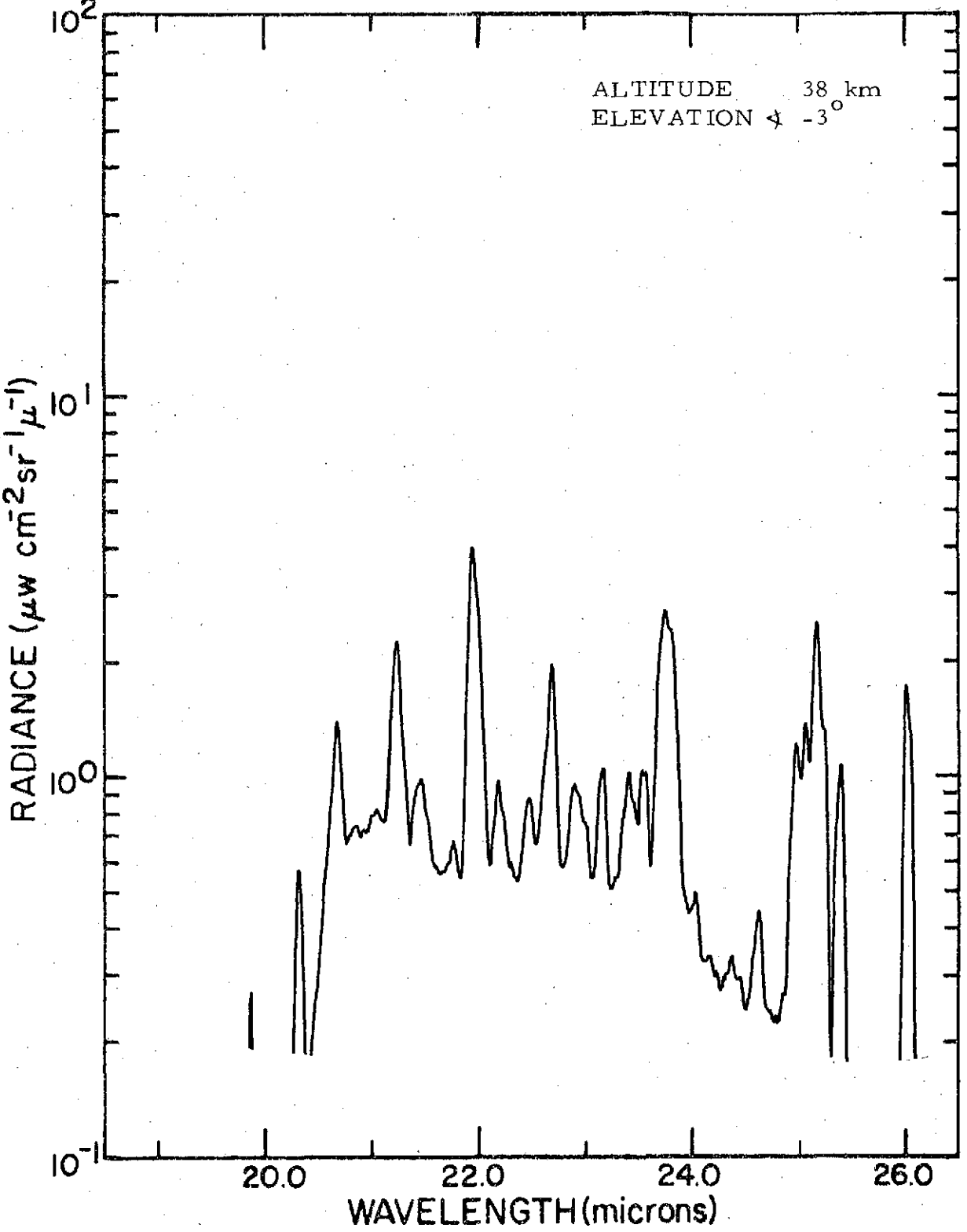

Figure 57. Radiance vs Wavelength for 27 June 1974 flight. Records 391-396 are co-added and time is 1143 MDT.

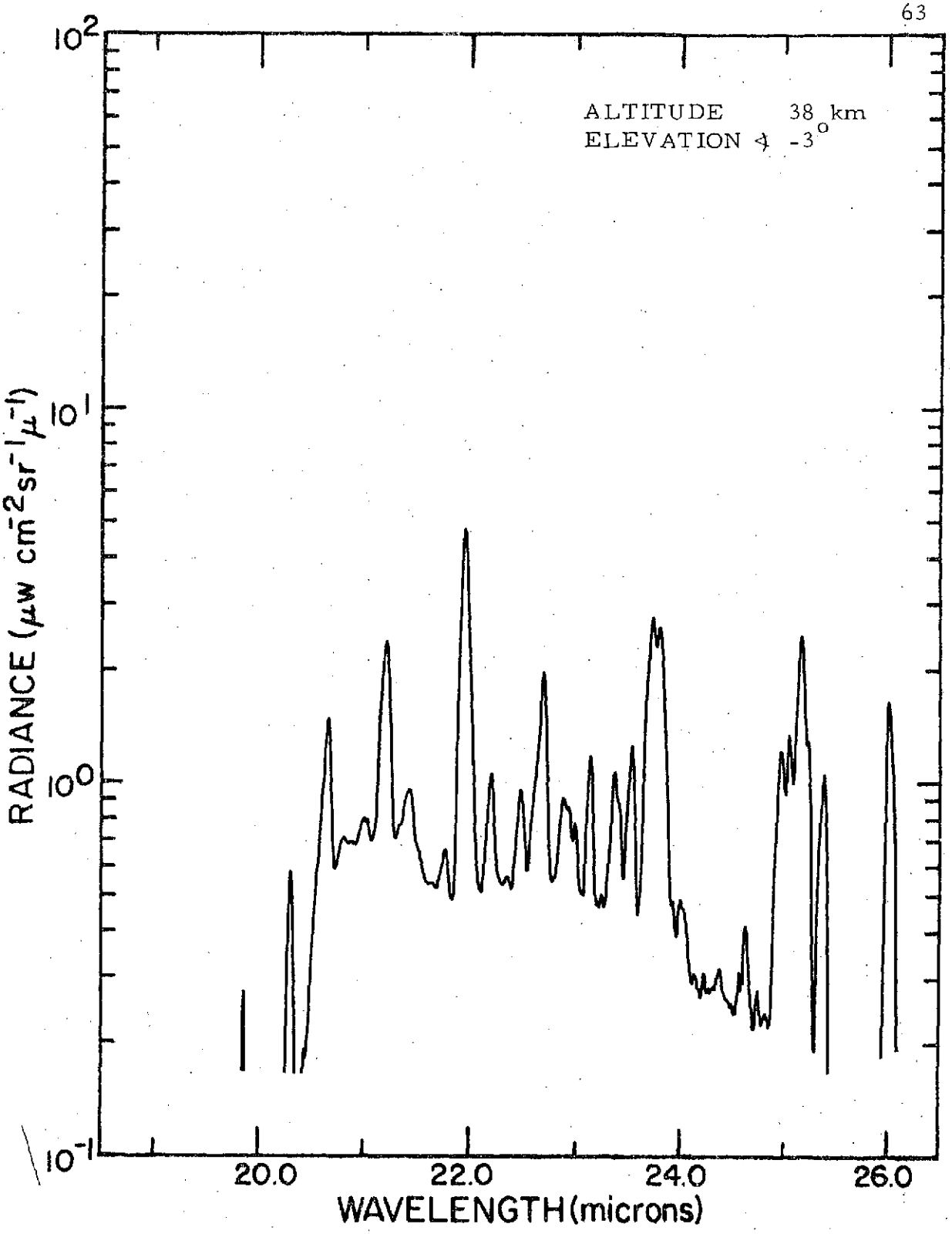

Figure 58. Radiance vs Wavelength for 27 June 1974 flight. Records 398-403 are co-added and time is 1148 MDT.

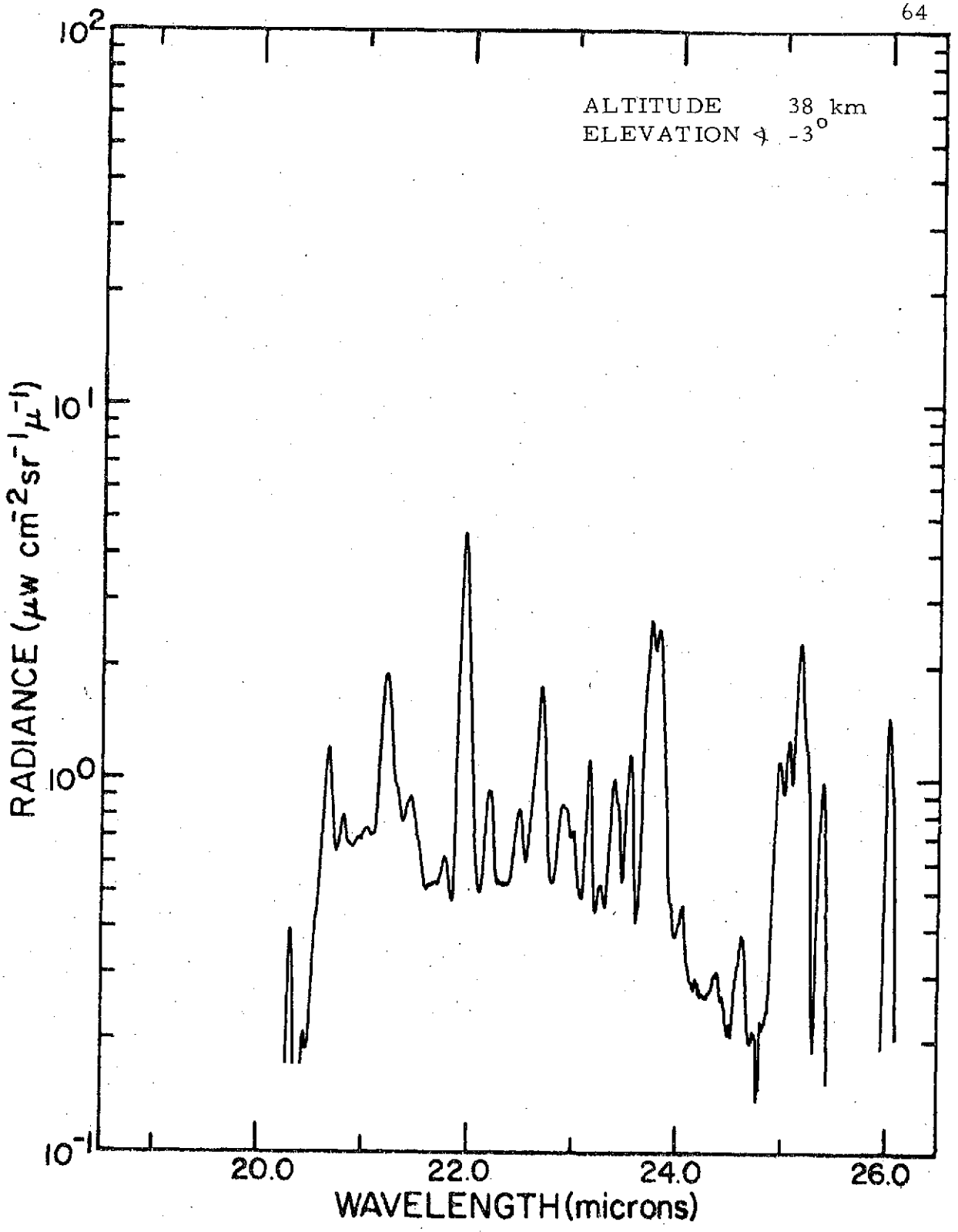

Figure 59. Radiance vs Wavelength for 27 June 1974 flight. Records 404-409 are co-added and time is 1152 MDT.